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Journal

of

THE ROYAL AERONAUTICAL SOCIETY

APRIL 1960

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None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

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NOTICES

Easter Holidays

The Offices of the Society will be closed from Thursday afternoon 14th April, until Tuesday morning 19th April.

Historic Aircraft Maintenance Group

Captain E. D. Ayre has taken up an appointment in Glasgow and has therefore resigned from his position of Chief Engineer of the Group. His resignation was accepted by the Steering Committee with regret. He has directed the work of the volunteers working on the Nash Collection since the Group was formed in 1958 and his guiding hand will be missed.

Mr. A. S. Hughes has been appointed to take over as Chief Engineer. Mr. Hughes is a Senior Development Engineer, B.O.A.C. He has been working as Deputy Team Leader of the Blériot team since the Group was formed and, during the past year, has also undertaken the duty of Honorary Storekeeper.

Mr. R. H. Doggett, Special Assignments Engineer, B.E.A., who undertook to act as Deputy Chief Engineer in January 1960 will continue to help the Group and is a most valued link with the Corporation which is the host of the Nash Collection until a more permanent home can be found for it.

Acknowledgment must also be made of the substantial contribution made by Mr. Peter Murray who, for the past year, has co-ordinated the difficult personnel situation and helped to keep the volunteer teams up to strength.

Scientific Relief Fund

The Council of the Royal Society has issued amended regulations for the Scientific Relief Fund of the Royal Society which is intended to aid scientific men, or their families, who require assistance.

The following is an extract from the regulations:—"Any member of a nationally recognized scientific Society within the British Commonwealth or the Republic of Ireland, acting through one of its officers, may bring cases of need to the attention of the Committee."

Sponsors of applicants for relief may obtain application forms from D. C. Martin, Esq., Assistant Secretary, the Royal Society, Burlington House, London, W.1.

Microfilmed Copies of the Journal and the Quarterly

Microfilm copies of the 1959 Journal and the 1959 Aeronautical Quarterly are now available from University Microfilms Ltd., 44 Great Queen St., London, W.C.2.

The complete volume of the Journal costs £1 15s. 6d. and the complete volume of the Quarterly costs 16s. 6d. They are available only to Members of the Society or to those who have subscriptions to these publications.

Second Halford Lecture—11th May

Mr. J. S. Alford, Design Engineer of the General Electric Company, U.S.A., will give the Second Halford Lecture at the Hatfield Branch on 11th May 1960. His subject will be "Power Plants for Supersonic Transports." The Lecture will be given at 6.30 p.m. in the Main Hall, Hatfield Technical College.

Acknowledgment

The Council wishes to acknowledge with thanks the generous gift to the Library of two broadsheets from Mr. E. C. D. Malone, Rosemorran, near Penzance. The broadsheets are:—"The Air Balloon—a new song on Mr. St. Croix's Ascension at Salisbury, 10th August 1786" and "On Mr. St. Croix's Second Ascension from the Market Place, Salisbury."

Lallement de Saint Croix first ascended, in this country, from Exeter on 19th June 1786. He made ascents, at Salisbury, on 10th August and 17th September 1786.

Annual General Meeting, 5th May 1960

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, will be held on Thursday 5th May 1960, at 5.30 p.m., in the Offices of the Society, 4 Hamilton Place, London W.1.

Agenda

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheet and Income and Expenditure Accounts of the Royal Aeronautical Society and Aeronautical Trusts Limited for the year ended 31st December 1959.
3. To receive the names of those elected to Council for the years 1960-63.
4. To elect the Auditors for the year 1960.
5. Any other business.

By order of the Council,
A. M. Ballantyne,
Secretary.

NOTE: In accordance with the By-Laws any member whose subscription has not been paid before the first day of April is not entitled to vote.

Light refreshments will be served after the **General Meeting of Voters of the Society,** *see* **p. XX.**

Supplement to Oxford English Dictionary

The following is the sixth list of aeronautical terms for the Supplement to the Oxford English Dictionary for which assistance in tracing early references is required. If members know of an earlier use than that given for any word in the following list they are asked to write to the Editor, Oxford English Dictionary Supplement, 40 Walton Crescent, Oxford, giving the reference(s), date, author, title, chapter and page. Other lists have been published in alternate numbers of the Journal since June 1959.

boom	1916	H. Barber *The Aeroplane Speaks.*
boss (on a propeller)	1916	H. Barber *The Aeroplane Speaks.*
boundary layer	1924	*Flight* 20 Nov.
bunt	1935	C. G. Burge (ed.) *Complete Book of Aviation.*
cabane	1914	*Aeronautical Journal* Oct.
cabin (of an aircraft)	1908	H. G. Wells *War in the Air.*
cadre squadron (Air Force)	1929	*Air Annual of the British Empire.*
cannon (aircraft gun)	1919	Radio Pamphlet No. 30 (*Signal Corps., U.S. Army*).
canopy (cockpit cover)	1939	*Jane's All the World's Aircraft.*
canopy (parachute body)	1940	*Chambers's Technical Dictionary.*
captive (of a small aircraft held by a larger, for launching)	1959	*Observer* 24 May.
carpet (air-bombing; U.K. quotations)	1944	T. H. Wisdom *Triumph Over Tunisia.*
carpet bombing (U.K. quotations)	1946	*Aviation Journal.*

New Year Honours List

Air Commodore C. A. Turner (*Associate Fellow*) received the C.B.E. in the New Year Honours List. Unfortunately his name was omitted from the list published in the February Journal.

GENERAL MEETING OF VOTERS OF THE SOCIETY

NOTICE IS HEREBY GIVEN that a General Meeting of Voters of the Society will be held at 4 Hamilton Place, London, W.1, on Thursday the fifth day of May 1960 at six o'clock in the afternoon for the purpose of considering and if thought fit passing the following Resolution:

"THAT the definition of the words "The Society" in By-Law 1 of the By-Laws allowed the 11th of January 1960 be amended by adding the words "and the Helicopter Association of Great Britain" after the words "Institution of Aeronautical Engineers."

By order of the Council.

A. M. Ballantyne

Secretary.

Dated the 7th day of March 1960.

Associate Fellowship Examination Results

The following candidates were successful in the Associate Fellowship Examination held in December 1959:

Part I—United Kingdom

R. F. Barton, Aerodynamics; A. R. Bell, Thermodynamics; H. Bennett, Strength of Aircraft Materials and Theory of Structures, Theory of Machines; N. Bonnor, Aerodynamics, Thermodynamics.

S. A. K. Choudhry, Pure Mathematics, Thermodynamics, Theory of Machines.

H. E. Edwards, Theory of Machines.

G. de Leersnyder, Pure Mathematics, Mechanics, Physics, Aerodynamics; R. H. Lloyd, Aerodynamics, Thermodynamics.

B. B. Nigam, Aerodynamics.

A. R. P. Phipps, Aerodynamics, Thermodynamics.

M. A. Siddiqui, Aerodynamics, Thermodynamics.

D. Thomas, Aerodynamics, Thermodynamics.

Part I—Abroad

K. P. Chopra (Calcutta), Thermodynamics.

C. V. Ramachandran (Bangalore), Aerodynamics.

Part II—United Kingdom

R. T. Bullus, Theory of Structures A, Economics and Management.

T. Coates, Aircraft Design and Development B, Theory of Structures A, Theory of Structures B, Theory of Structures C.

I. J. Ford, Theory of Structures B, Aircraft Design and Development A.

R. Jennings, Theory of Structures A, Theory of Structures B, Aircraft Design and Development A, Aircraft Design and Development B.

J. B. Pearson, Aircraft Design and Development A, Aircraft Design and Development B, Air Transport; B. Pitchfork, Theory of Structures A, Theory of Structures B, Theory of Structures C.

A. F. Schofield, Theory of Structures A, Theory of Structures B, Theory of Structures C.

Part II—Abroad

P. Kunhiraman (Poona), Thermodynamics and Theory of Machines, General Design, Piston and Turbine Engines, Piston and Turbine Engines.

K. G. K. Pillai (Delhi), Piston and Turbine Engines.

R. Sampath (Madras), Thermodynamics and Theory of Machines, Economics and Management; V. V. Samuel (Calcutta), Thermodynamics and Theory of Machines, General Design, Piston and Turbine Engines, Piston and Turbine Engines.

DIARY

LONDON

22nd April

Agricultural Aviation Group Lecture—Pilot Training. Capt. Richard Bradbury and J. M. McMahon. Library, 4 Hamilton Place. 7 p.m.

5th May

Annual General Meeting—4 Hamilton Place. 5.30 p.m. General Meeting. 6 p.m.

19th May

Forty-Eighth Wilbur Wright Memorial Lecture—Mathematics and Aeronautics. M. J. Lighthill. Institution of Mechanical Engineers, Birdcage Walk. 6 p.m. (Tea 5.30 p.m.)

ASTRONAUTICS AND GUIDED FLIGHT SECTION

12th May

On Reducing Costs of Space Research. J. E. Allen. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea 5.30 p.m.)

ROTORCRAFT SECTION

6th May

The Personal Helicopter. J. S. Shapiro. Library, 4 Hamilton Place. 6 p.m.

HISTORICAL GROUP

17th May

Lecture by Sir Thomas Sopwith, C.B.E. Institution of Mechanical Engineers, Birdcage Walk. 6 p.m. (Tea 5.30 p.m.)

BRANCHES

22nd April

Birmingham and Wolverhampton—Film Night. The Engineering Centre, Birmingham. 7.30 p.m.

27th April

Christchurch—Annual General Meeting. Operational Problems in Supersonic Flight Testing. Wing Cdr. R. P. Beamont. King's Arms Hotel. 7.30 p.m.

Coventry—Annual General Meeting and Films. Herbert Art Gallery. 7.30 p.m.

Hatfield—Supersonic Transports. D. G. Brown. de Havilland Restaurant. 6.15 p.m.

Preston—From Aviation to Astronautics. J. E. Allen. Queen's Hotel, Lytham. 7.45 p.m.

Weybridge—Annual General Meeting. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

28th April

Yeovil—Annual General Meeting. Park School. 7.30 p.m.

11th May

Chester—Annual General Meeting and Film Show. Lecture Theatre, Grosvenor Museum. 7.30 p.m.

Hatfield—Second Halford Lecture—Power Plants for Supersonic Transports. J. S. Alford. Hatfield Technical College. 6.30 p.m.

Elections

The following is a list of new members and transfers of membership of the Society:—

Associate Fellows

Charles John Adey (*from Student*)
John Anthony Airey
Clifford Ernest Allen (*from Graduate*)
John Anthony Beasley (*from Graduate*)
John Archibald Cameron
Reginald Harrington Capp
John William Child (*from Graduate*)
Edmundo Gomes Ferreira da Silva (*from Graduate*)
David Alan Drane (*ex Graduate*)
Anthony John Duke
Clive Ellam (*from Student*)
Robert Terence Elmes
Peter Garnell
Harry Christopher Gear
Wilfred Ronald Gellatly
John James Georgas
Stanley George Glaze
Leonard Goland
Norman Charles Hanslip
Arthur Frederic Hindell (*from Associate*)
William Walton Hinks
Charles Thomas Denneny Hosegood
John Victor Houghton (*from Student*)
William Edwin Billing Hurst (*from Associate*)
Derek Anthony Jackson (*from Graduate*)
John Einion Glyn Jones (*from Graduate*)
Willy Albert Kuipers
Maurice Arthur Laceby
Geoffrey Francis Langdon (*from Graduate*)
John Stewart Latham
Stuart Gordon Lennox (*from Student*)
Eugene Kurt Liberatore
Ralph Butterworth Lightfoot
Edward Ernest McCullough
Donald Lowson McDiarmid
John MacKenzie
William Harry Maskell
Roderick James Milroy
Paul H. L. Morain
Jack Audrey Newton (*from Associate*)
Francis O'Hara
Eric Thomas Pointon
Ajit Kumar Ray
Otto Reder
Keith William Stanley Richards (*from Graduate*)
Henry Gerald Rossiter
Igor Alexis Sikorsky
Peter Burke Sindery
Harjinder Singh
August Stepan
William Stewart
Walter Strachan
Barry Stephen Thornton
Frederick George Toone (*from Associate*)
James Gillette Try (*from Graduate*)
Robert Ian Walton
Frederick Charles Watson (*ex Associate*)
William David Webster
John Herbert Williams
John Woodman

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William Henry Armstrong
Charles Arthur Bates
Reginald Millis Bowmer
Allan Charles Braby
John Francis Brennan
Derek Huddlestone Cook
Jack Creaton
John Reginald Dowling
Kenneth Fry
William Jennings Gibson
W. Clifford Hammond-Adler
Arthur Frederick Ernest Hessel
Frederick William Higginson
George Geoffrey Holt
Dennis Christopher Lawrence Kearns
Brian Mellor (*from Companion*)
Thomas Thornton Miller
George Herbert Moysen
Ernest Edward Albert Peake
Thomas Reynolds Pierpoint
Frank William Henry Ponsford (*ex Student*)
Nigel Price (*from Student*)
Kenneth John Riddy
Ian Drysdale Roxburgh
Ernest Smith
Francis Henry Smith
Geoffrey Roger Cole Spencer
Alexander McKay Sinclair Steedman
Frederick Leslie Swain
John William Ransom Taylor
Gordon Vallins Elliott Thompson
Eric Arthur Voss
Ian Vivian Wansbrough
Robert William Washer
Harry Nigel Newson Wemyss (*from Student*)
Peter Rene Duff Wilson

Graduates

Michael Ernest Barnard (*from Student*)
Anthony James Bates
John William Britton (*from Student*)
Peter Derek Chappell (*from Student*)
George Howard Davison (*from Student*)
John Macdonald Lawson Dook (*from Student*)
Bruce Anderson Graham (*from Student*)
Brian William Loughridge (*from Student*)
Russell Estcourt Luxton
Kenneth Parker
Geoffrey Norman Sage (*from Student*)
Michael Walter Ratcliffe Seel (*from Student*)
Patrick Michael Gordon Spence (*from Student*)
Stanley James Stevens
Carl Pymm Stocks
Harold Edward Thomas
Roynen Titchen (*from Student*)
Alan Henry Tucker
Christopher Bernard Wheble (*from Student*)
Alun Williams
Kenneth Wisker
Alan Anthony Woodfield (*from Student*)

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Barry Bamford
Bryan Bowen
Gordon William Camp
Anthony Carter
Terence Coxall
Kevin Crawley
Bruce Richard Ellis
John Edward Iles
Ian Jones
David Graham Kite
Michael John Lawes
Brian William Mattinsley
John Michael Pease
David Robertson Shepherd
Reginald Edward Wooller

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M. H. Hancke
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Patricia Rowand McKim
Arthur Ernest Page
Thomas Francis Peppitt
Lothar G. S. Prang
Leslie Thomas Ricketts
Otto Rietdorf
William Gustav Ruff
Alan Simmons
Basil Smallpeice
Jan A. C. Tillema
Paul Dimitreff Wolkovich

News of Members

N. L. Angell (*Associate*) formerly Deputy Chief Inspector, F. G. Miles Ltd., is now Chief Inspector, Hobourn Aero Components Ltd., Strood, Rochester.

G. W. T. Bees (*Associate Fellow*) formerly with the Airspeed Division, de Havilland Aircraft Co. Ltd., Christchurch, is now Senior Designer, Systems (Sea Vixen), at Hatfield.

C. H. Bickerdike (*Associate Fellow*) formerly Technical Director, White & Riches Ltd., is now Managing Director of the newly formed Company, Electronic Control Engineering Ltd. (ECE Ltd.) Haywards Heath.

Air Vice-Marshal B. A. Chacksfield (*Associate Fellow*) formerly Director G. W. (Trials) M.O.S. and R.A.F., has been appointed S.A.S.O., Technical Training Command, and has been made Air Vice-Marshal.

C. H. Chichester Smith (*Associate Fellow*), a member of the board of The Fairey Company Ltd., has been appointed Managing Director.

J. P. Dainty (*Associate Fellow*) formerly Production Development Engineer at Vickers-Armstrongs (Aircraft) Ltd., Weybridge, is now Engineer II, responsible for Machine Tool Development, Atomic Weapon Research Establishment, Aldermaston.

D. N. Foster (*Graduate*) formerly with Bristol Aircraft Ltd., is now an Assitsant Lecturer, Department of Aeronautical Engineering, College of Technology, Bristol.

G. S. Henderson (*Associate Fellow*) formerly Development Engineer, D. Napier and Son Ltd., Luton Airport, is now a Senior Designer, James Archdale and Co. Ltd., Worcester.

A. T. Hills (*Associate*) formerly Senior Technician, Machine Control Department, Hilger and Watts, is now Experimental Officer, Trials Group, Engine Test Facilities Department, N.G.T.E., Pyestock.

J. C. Jones (*Associate*) formerly Senior Design Draughtsman, Smiths Aircraft Instruments Ltd., Cheltenham, is now Senior Design Draughtsman, Dowty Nucleonics Ltd.

Flt. Lt. R. C. Manocha (*Associate Fellow*) formerly with the Inspection Office, Northern Area, is now Resident Senior Aircraft Inspector (Manufacture) at Hindustan Aircraft Ltd., Bangalore.

H. E. Parish (*Associate Fellow*) formerly Senior Section Leader (Structures), Hunting Aircraft Ltd., is now Chief Stressman.

P. W. Parish (*Associate Fellow*) formerly Design Engineer, S. Smith and Sons (England) Ltd., Cricklewood, is now a Senior Structural Design Draughtsman, de Havilland Aircraft Co. Ltd., Hatfield.

S. H. PARKER (*Associate Fellow*) formerly Assistant Chief Draughtsman, Heston Aircraft, is now a Section Leader, design office, Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

R. C. PENNICOTT (*Associate Fellow*) formerly with Portsmouth Aviation Ltd., as a Senior Structural Engineer is now a Stress Engineer, English Electric Aviation, G.W. Division.

S. RAMAMRITHAM (*Associate Fellow*) formerly Deputy Director of Research and Development, Technical Centre, Civil Aviation Dept., New Delhi, is now Director of Research and Development.

J. A. ROSS (*Associate*) formerly London Manager of Trans-Canada Air Lines at London Airport, is now Assistant Director of Passenger Service, Trans-Canada Air Lines, Montreal.

ALLAN SADLER (*Associate Fellow*) formerly Manager of Engineering and Development Laboratories, Smiths Aircraft Instruments Ltd., is now Research and Development Manager, Ultra Electronics Ltd.

C. E. SPEDDING (*Associate Fellow*) formerly a Senior Stressman and Technician, Saunders-Roe Structures Ltd., is now a Development Engineer in the Group Research Laboratories of Guest, Keen and Nettlefold Ltd.

Wing Commander R. A. WATTS (*Associate Fellow*) has been posted from the Air Ministry and is now Wing Commander Flying at the Experimental Flying Department, R.A.E., Farnborough.

LECTURE SUMMARIES

SUPERSONIC AIRCRAFT—PROMISE AND PROBLEMS

M. B. MORGAN, C.B., M.A., F.R.Ae.S.

Given on 17th March 1960—To be published

Attention will be focused on medium and long range supersonic transport aircraft.

The subsonic transport aircraft picture since the twenties is first briefly surveyed. It is pointed out that the aircraft that have found widespread acceptance on the routes have clustered into a number of families—first biplanes; then monoplanes with piston engines; monoplanes with turbo-prop engines; and now the big swept-wing transports with turbo-jet engines. These themes have overlapped; each successive family has flown faster and higher than the previous one; and this has been accompanied by a steady *reduction* in direct operating costs. Illustrations are given which indicate clearly that for subsonic aircraft any ideas that, up to the present, speed has been expensive are fallacious. Two other present day lessons are important, since they colour thinking when supersonic transports are approached. Apart from it being cheap to go fast, it has proved cheap to build big—a good formula for low costs is to make the aeroplane as big as you dare *and fill it.*

An attempt is made to predict, on technical grounds, the likely families of supersonic aircraft. There is little case for very short haul machines to go supersonic. For medium ranges (stage lengths of 1,500 nautical miles) it is suggested that current advances in aerodynamic knowledge of sweepback will allow cruising speeds to rise to M 1·2; use of swept or M wings will allow this to be done without any large increase in operating costs. It is felt that a rise to such a speed for the medium range aircraft is inevitable, and forms a natural development from present and projected high subsonic jet transports. Speeds higher than M 1·2 are unlikely with "swept wing" transport aircraft.

The most attractive field for supersonic transports is long range; this must embrace the London-New York stage length. The technical factors are examined, and it is shown that reasonably economic aircraft can be evolved at about M 1·2; that the region M 1·2 to M 1·8 is unattractive; but that the Mach number region 1·8 to about 3·0 is singularly attractive in terms of potentially economic aircraft. Since the technical difficulties of producing an aircraft at the lower end of the 1·8 to 3·0 region are comparable with those of the 1·2 machines, and direct operating costs also show promise of being comparable, there is no strong case for the M 1·2 trans-Atlantic machines.

A Mach number of about 2·0 may be a natural "fit" for a long range transport, in going fast enough to reap the benefits of really high speed on engine and aerodynamic efficiency, and not so fast as to run bull headed into kinetic heating problems. London-New York time of flight is reduced dramatically from the 7 hours of the subsonic jets to 3 hours. Long slender shapes, with subsonic leading edges and supersonic trailing edges, will give sufficiently high L/D while the aspect ratio is high enough for a reasonable compromise between cruising efficiency and reasonable approach speed. The various problems thrown up by such machines—aerodynamics, engine, structure, noise, traffic control—are touched on.

"Long slender" wing themes can carry you up to Mach numbers of somewhat over 3·0, but aspect ratio decreases will make the landing compromise increasingly awkward; V.T.O. or variable geometry schemes may come into their own at these higher Mach numbers. The big problem once M 2·0 is exceeded is that of kinetic heating, reacting on structural and engine design, choice of materials, and cooling. All these difficulties can be overcome. They are being faced in order to cut only a further ¾ hour off the airborne time, but as against this passenger appeal may be high. Light alloy will not take you much beyond M 2·0 as a material for airframe construction. Once steel is adopted there will be every inducement to approach M 3·0, in spite of the extra development costs and the greater uncertainty in direct operating costs. For any particular country, weighing up the pros and cons of what might loosely be termed the M 2·0 versus M 3·0 contest will demand nice judgment—centring around markets, timing and costs. In the context of the world aeronautical picture, however, neither theme can be dismissed.

Between M 3·0 and M 5·0 a new aerodynamic theme of "shock interference" may emerge which will allow aspect ratio to rise. Preliminary studies do not promise particularly economic values for the operating costs of long range aircraft cruising at between M 4·0 and M 5·0 with ramjet propulsion; while, the time saving on the London-New York run is far from impressive over and above that achieved with M 2·0 or M 3·0 machines. As knowledge advances something of interest may emerge at these speeds, however, particularly for still longer ranges. The even more extreme theme of *economic* flight at hypersonic speeds on semi-ballistic trajectories can be studied with interest, but can safely be put some way ahead in time, and is probably most attractive for very great ranges.

Man Powered Aircraft Group

AERODYNAMICS OF MAN POWERED FLIGHT—WITH SPECIAL REFERENCE TO INFLATABLE WINGS

D. PERKINS

Given on 25th March 1960

The lecture will discuss:

1. The minimum essential features of an aircraft designed primarily for straight and level flight.
   (*a*) Limitations on control.
   (*b*) Methods of applying a man's power and their efficiency.
   (*c*) Factors affecting design take-off speed.
   (*d*) Power output and its measurement.
2. Light-weight propeller construction.
   (*a*) Factors affecting the choice of diameter.
   (*b*) The effect of centrifugally applied suction to propeller blade surfaces.
3. Fuselage design.
   (*a*) Number of occupants.
   (*b*) Their effect on design.
   (*c*) The attitude of the pilots and their position.
   (*d*) Shape.
   (*e*) Number of wheels, if any
   (*f*) Wheel friction and surface effect.
   (*g*) Value of preliminary wheel drive.
4. Materials used in inflatable wings.
   (*a*) Manufacture, construction and assembly of proofed textile.
   (*b*) Its characteristics, strength and weight.
   (*c*) Its vulnerability and durability.
5. Construction of Inflatable Beams.
6. Methods of achieving rigidity.
7. The geometry of inflated aerofoils.
   (*a*) British and American approach.
   (*b*) Accuracy of the finished products.
8. The choice of a suitable aerofoil, its aspect ratio, taper ratio and plan form.
9. Methods of checking performance on runway and some results.
10. Instruments for low speed aircraft.
    (*a*) Air speed indicators.
    (*b*) Ground speed indicators.
11. Comments on other methods of design produced to date.

The Journal of the Royal Aeronautical Society

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VOLUME 64 APRIL 1960 NUMBER 592

The Low Speed Approach and Catapult Launch Problems in High Performance Naval Aircraft

by

Lt.Cdr. D. J. WHITEHEAD, A.F.C., A.R.Ae.S., R.N.

(Chief Test Pilot, Blackburn Aircraft Limited)

1. Introduction

In the first half of the paper some of the basic aerodynamic engineering and piloting problems that have been encountered during the design and development of modern naval deck landing aircraft are enumerated and described. Such aircraft, of basically swept-wing configurations and high transonic or supersonic performance, have to be capable of being flown comfortably under full pilot control at the low speeds expected for carrier deck landings.

In Part II, the many devices of aerodynamic and engineering design will be described which have been evolved in an attempt to overcome or minimise the problems.

It is also my intention to avoid bringing in the more abstruse technicalities of pure aerodynamics, but it has been necessary to include some of the terminology in current use in the Aircraft Industry.

This material, as described, will be used as a background to be highlighted, where appropriate, by personal experiences during the test flying programmes on such aircraft, together with those of fellow service and civilian test pilots engaged in similar evaluation programmes.

2. Summary of Problems

The new generation of transonic and supersonic aircraft intended for use from the confines of a carrier deck involve problems of aerodynamic wing design that have not previously been encountered, the solutions of which have taken many forms.

The conflicting requirements of the two ends of the speed range demanding thin aerofoil sections (low thickness/chord ratio) on the one hand and high camber on the other, can no longer be met with normal flap systems, however complex they may be.

Two accepted methods of augmenting the lift of a wing either by increasing its area or the maximum lift coefficient ($C_{L\max}$) both involve problems. The former can be incorporated only at some sacrifice of aircraft performance in other departments, notably its capacity for high-speed flight. In the second case the $C_{L\max}$ is usually limited at a fairly low value in view of the thin-wing and swept-wing requirements at transonic and supersonic speeds.

The drooped leading edge has been successfully used, but it is probable that not much more can be done to the aerofoil section without detriment to high-speed characteristics. An effective method therefore of increasing the lift coefficient of a wing under critical low-speed conditions is to improve flap efficiency.

In addition to the problems of increasing the available lift from a given wing, undesirable characteristics, many of which are associated with swept wings, manifest themselves at the high wing incidences used. Such items as pre-stall instability, rapid increase in induced drag, and so on, produce control problems before, and entirely divorced from, the true wing stall itself.

In earlier aircraft, the onset of wing stalling characteristics normally dictated the minimum approach speed used for deck landings. The new generation of aircraft, however, in spite of all the aerodynamic trickeries for increasing $C_{L\max}$, are forced to use approach speeds considerably higher than those corresponding

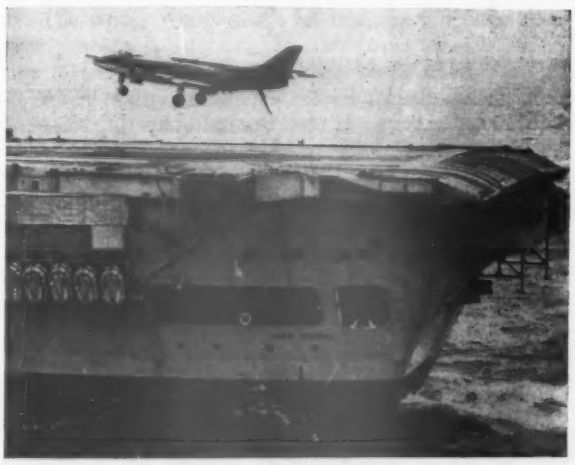


FIGURE 1. A Scimitar aircraft about to make a perfect deck landing on H.M.S. *Ark Royal*.

A Lecture given before the Brough Branch on 9th December 1959.

to $C_{L_{max}}$ due entirely to the onset of the undesirable characteristics previously mentioned. In addition, poor control response, particularly of the ailerons, may well dictate an even higher speed for comfortable control.

3. Carriers and Associated Equipment

The structure of carriers by virtue of linear dimensions, structural strength and arrester and catapult capacities, impose extra limitations upon aircraft design not present on shore-based aircraft.

These have a direct effect upon (*i*) aircraft linear dimensions (length, height and span), (*ii*) speeds and weights of touchdown, (*iii*) speed and weight at launch, and (*iv*) undercarriage strengths. Thus these limitations have a direct repercussion upon basic aerodynamics, in particular stability and the low speed approach capabilities.

As an indication of these limitations some of the dimensions of, and equipment in, H.M.S. *Victorious* are described. Fig. 2 shows the flight deck dimensions and other statistics are: —maximum lift load 40,000 lb., hangar dimensions 360 ft. by 65 ft. by 17 ft. 6 in.

Mark 13 Arrester Gear

On the flight deck there are four arrester wires each of which can accept, for example, an aircraft weighing 25,000 lb. picking up the wire at a maximum relative velocity of 115 knots.

There is a certain interchange of weight and relative velocity possible, simply expressed in Fig. 3, but the problems of "snatch load" on the cable itself will always impose an upper limit on velocity alone and is a function of the material itself.

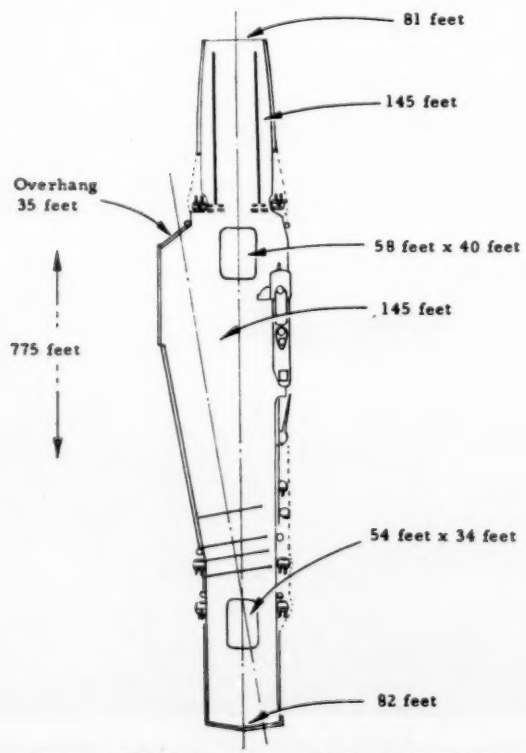


FIGURE 2. H.M.S. *Victorious*. Flight deck dimensions.

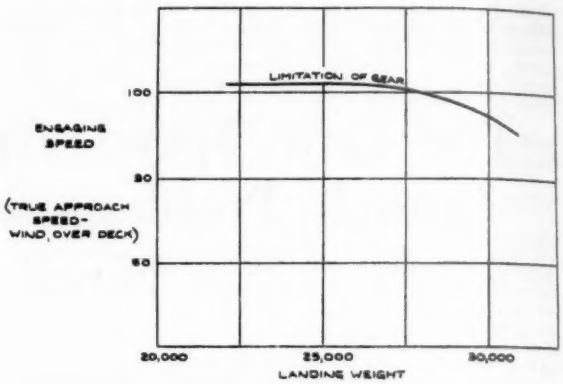


FIGURE 3. Ship's arrester gear limitation.

B.S.4 Catapults

These two parallel track steam-operated catapults are capable of projecting aircraft at a range of final relative velocities dependant upon aircraft weight, *e.g.* 110 knots end speed for 30,000 lb. weight.

British Carriers

At the present time there are seven British Carriers in operable condition—H.M.S. *Centaur*, H.M.S. *Albion*, H.M.S. *Bulwark* (Commando operations only), H.M.S. *Hermes*, H.M.S. *Ark Royal*, H.M.S. *Eagle* (undergoing modernisation programme) and H.M.S *Victorious*.

4. Maximum Usable Lift Coefficient

It immediately becomes clear that when the designer has made his weight study in the light of the Director of Aircraft Welfare sortie requirements, he will be faced with a firmly fixed landing weight. This is usually the basic weight of the aircraft with a small fuel reserve which would be necessary after a sortie. It may include the weight of expensive weapons which may not have been used during an abortive flight.

The basic wing design, including thickness/chord ratio, aspect ratio and area, is most likely to be fixed by the main role of the aircraft. With the landing wing loading determined and the approach speed requirement laid down, the designer is able at once to assess the lift coefficient which is necessary for the carrier approach.

With modern aircraft with thin, swept and low aspect ratio wings, the stalling incidence and maximum lift coefficient are no longer sharply defined and the problem becomes not just a matter of achieving a particularly high maximum lift coefficient, but ensuring that a practicable, usable lift coefficient at a workable incidence is obtained, which is not prejudiced by pre-stall handling deficiencies.

Invariably the value of this approach lift coefficient will be high on naval aircraft and the designer will be forced to adopt elaborate flap arrangements. He may even have to resort to boundary layer control devices.

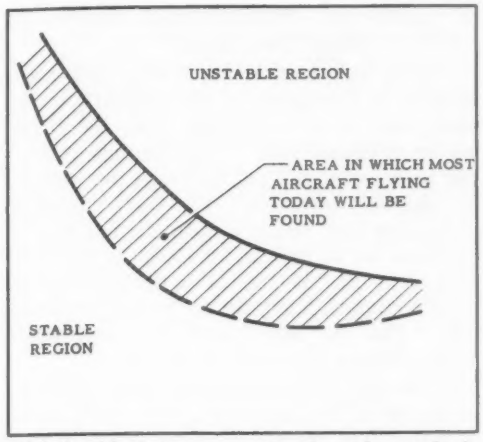


FIGURE 4. Relationship between aspect ratio and sweepback.

The range of values of some statistics relevant to wing form on recent naval aircraft are: —

Thickness/chord	6 to 10 per cent
Max. C_L	1·5 to above 2
Sweep	20° to 45°

5. Pre-Stall Stability and Low Speed Control

It is important that the designer should, in early model and flight tests, give considerable attention to the pre-stall stability of the aircraft and the general handling properties at low speeds.

A large number of low speed problems have arisen since the war, most of them associated with swept wings. There is quite a clear relationship between aspect ratio and sweepback which is illustrated in Fig. 4.

It is important to realise that this represents a wing characteristic alone (*i.e.* tail off).

The tailplane position is probably the biggest single factor, other than this sweepback/aspect ratio combination, affecting pitch-up at high lift coefficient.

6. Pre-Stall Longitudinal Instability

Pre-stall longitudinal instability at high Mach numbers and at low speeds has provided one of the biggest aerodynamic problems since the war. This has been largely attributable to swept wings which, when operating at high lift coefficients, tend to tip stalling.

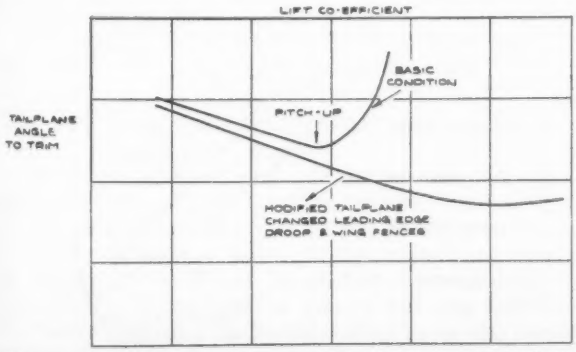


FIGURE 5. Effect of various modifications on longitudinal instability.

This produces a forward movement of the aerodynamic centre and an increased downwash from the centre section. A de-stabilising moment is produced and the all too common "pitch-up" phenomenon occurs.

The low-speed "pitch-up" met with in the approach configuration has been an effective limit to the usable lift coefficient on some aircraft. This can be partially eliminated by careful modifications to the amount of leading edge droop fitted to the wings and by provision of boundary layer fences.

The de-stabilising effect of the increased downwash with increase in wing incidence has given the aircraft designer problems with regard to positioning of the tailplane. The most recent tendency has been towards a low set tailplane, as is found in the Lightning. In the case of the Scimitar aircraft a change of tailplane configuration from one of 10 degrees dihedral to 10 degrees anhedral produced a marked improvement, as shown in Fig. 5.

7. Increase in Roll Due to Sideslip (l_v) at High C_L

This is the familiar dihedral effect, *i.e.* if an aircraft with dihedral is side-slipped to port the aircraft will tend to roll to starboard, due to increase of incidence of the port wing. This characteristic has been made use of in the past to give aircraft good natural lateral stability. On swept-back wings, however, the dihedral effect increases with increase in wing incidence, *i.e.* the negative value increases. Thus an aircraft with normal dihedral for stability during high-speed flight may well be too stable at high incidence and, indeed, most modern aircraft are given zero *or even negative* dihedral, *i.e.* anhedral, to avoid this characteristic, *e.g.* the F.104. Care has to be taken, however, as if the dihedral effect becomes too small, or even positive, during the very low incidence achieved during high-speed flight, then recovery from a limiting Mach number may be critically effected.

There is a relationship (or exchange rate) between *sweepback* and *dihedral* and this is in the ratio of 10° for 1°.

The whole "derivative" relationship is a very complex problem worthy of a separate paper in itself. Each new aircraft has a completely new set of relative effects.

As a matter of interest, if aileron droop or other forms of full-span flap are used in any significant form, l_v is doubled.

8. Poor Aileron Effectiveness at High Incidence

It is probably well known that under conditions of large pressure differential occurring on a swept wing, *e.g.* under conditions of large incidence, the air flow tends to diverge towards the wing tip. This is a cumulative effect and the air flow in the vicinity of the wing tip has a marked outward divergence relative to the chord line. (*See* Fig. 6.)

Thus, due to this virtual spanwise flow in the vicinity of the aileron, the component of the air flow parallel to the chord of the aileron itself is considerably reduced and, consequently, so is the aileron effectiveness.

FIGURE 6. Illustrating divergent air flow towards the wing tip.

In addition, the considerable thickening of the boundary layer, plus the tendency for air flow breakaway in the vicinity of the aileron, further reduce the aileron's potential effectiveness. Thus control of lateral displacements of the aircraft can become considerably more difficult under conditions of large incidence on swept wing aircraft.

To this problem one can ally another associated with artificial feel systems, breakout forces and friction loads in particular. Some aircraft have hydraulic boosters to overcome lateral breakout forces; these always tend to be high in naval aircraft due to folding wings necessitating complicated cable runs with their associated high friction loads.

Other problems of lateral rocking can occur, associated with power control aileron jack valves having out-of-balance characteristics. This problem can be aggravated in aircraft with high lateral inertia (fuel in the wings) and low damping in roll.

The drooping of ailerons in a full-span flap function now being adopted in current aircraft, such as the Blackburn N.A.39, can bring in its wake further aggravation of the normal loss of lateral control unless the local air flow is assisted by a super circulation facility.

In addition, however, the age-old problems of aileron drag return again and loss of lateral response can result from the adverse yaw induced.

The use of variable gearing and auto-stability both have a bearing on this problem and are dealt with in detail later.

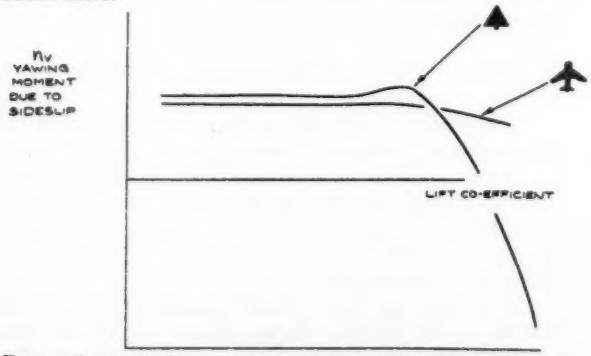


FIGURE 7. Variation of n_v with lift coefficient for delta and moderately swept-back aircraft.

9. Loss of Weathercock Stability (n_v) at High Incidence

As is well known, the weathercock stability of an aircraft is a measure of the aircraft's tendency to set itself into the relative wind, were the aircraft pivoted about its vertical axis. Contributions to this arise from the body, wing and tail, although the wing contribution is relatively negligible. The body contribution is destabilising and depends upon the amount of side area fore and aft of the c.g. Stability is achieved by means of a fin as the "lift" forces on the fin, when sideslipping, have a moment about the c.g. tending to reduce the sideslip. This tail contribution to n_v depends on the fin area, position and air flow over it.

The fin contribution to this stability decreases markedly at high incidence, due mainly to the fact that it comes into the disturbed air flow arising from body and canopy vortices and possible wing centre section air flow separations. This should be obvious from Fig. 8.

The increase in width of fuselages accommodating engines close to the fuselage itself will aggravate this problem. This is very evident in Scimitar, Sea Vixen and the N.A.39.

In addition, the change in wing downwash effect with increase in incidence may cause a further loss of effectiveness and finally, there is a slight shortening of the effective moment arm that the fin has about the aircraft's vertical axis of rotation. This can be seen from Fig. 8 to be a reduction from "L" in straight and level flight to "M" at high incidence.

10. Poor Longitudinal Response to Tailplane Movement at Low Speed

In aircraft with fully-powered slab tailplanes the stick-to-tailplane gearing must be such that at high indicated air speeds the response of the aircraft for a given stick deflection, resulting from the corresponding tailplane movements, must not be too sensitive otherwise it becomes impossible to fly the aircraft accurately under these conditions. Therefore, a compromise in stick/tailplane gearing is normally adopted, giving reasonably sensitive control over the normal cruising speed range. This, however, may result in large stick, hence tailplane, deflections being required for control at low air speeds. If this is coupled with a large trim change due to flap

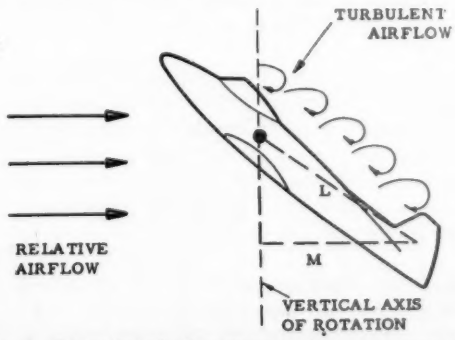
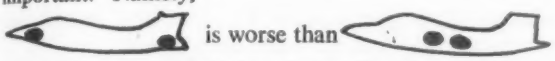


FIGURE 8. Disturbed air flow from body and canopy affecting the fin.

lowering and so on, resulting in the neutral trim position of the control column being fairly close to either its fully aft or fully forward position, then insufficient control angle could remain in one particular direction to cope with further flight requirements.

Another factor with the current trend to large naval aircraft of over 30,000 lb. weight, with relatively long fuselages, is that the pitching inertia of this long heavy body is such that large control movements will be required to initiate movement; this factor is quite noticeable when flying this type of aircraft.

One point of note, so far as longitudinal inertia is concerned, is that the distribution of the mass is all-important. Namely,



is worse than

Another characteristic of the fully-powered slab tailplane, the effect of which superimposes itself upon the other factors, is of phase lag between input and output of the hydraulic jack valve which results in a positive lag between control column movements and tailplane movement, hence aircraft response.

These characteristics may apply also, of course, to the other flying controls, particularly ailerons, and the whole situation may be further complicated by the use of artificial feel systems associated with fully-powered controls.

Another factor associated with this problem is the need to balance out excessive pitching moment on swept-wing aircraft when fitted with high C_L devices, which has a bearing upon the tailplane size and deflection during approach to land. The following figures give comparative values associated with each function: —

Configuration	*Pitching moment factor*
Wing and flap	1·0
Wing + flap + flap blow	1·3
Wing + flap + droop (*no* blow)	1·8
Wing + flap + droop (+ blow)	3

Hence the need to use excessive deflections of tailplane during approach and blown take-off. The tailplane drag is considerable and, if excessive angles are used, some loss of effectiveness will result with a possible danger of stalling, on take-off in particular.

A few more comments, together with the relevant graphs, will be mentioned in later sections on tailplane flap and blowing.

The use of datum trimming has been found necessary, due to use of larger tailplane angle range.

11. Buffeting and Wing Dropping at High Incidence

These are characteristics previously met with in earlier aircraft but they tend to become more of a problem with swept-wing aircraft due to the tendency for air flow breakaway in the vicinity of the wing tips. The breakaway itself may be gradual and may make itself felt by an increase in general airframe buffet. This buffet level may be further added to by the fact that because of the necessity to have maximum drag on the approach, by virtue of Vi_{md} consideration (*see* following Section) the air brakes will normally be extended. If the wing tip breakaway is severe and occurs on one wing before the other, then marked wing dropping will occur which can prove rather disconcerting if it is associated with loss of aileron effectiveness. One reason for this was outlined previously.

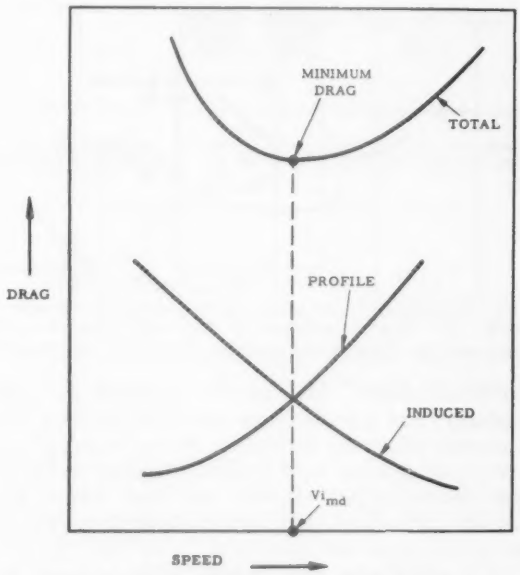


FIGURE 9. Illustrating the basic definition of Vi_{md}

12. Speed/Height Stability (the Vi_{md} Problem)

It is well known that there is a speed at which the aircraft drag is a minimum, known as Vi_{md}. (Fig. 9.)

At speeds below this, a reduction in speed results in increase of drag, which in turn causes a further loss of speed. This simple effect is usually revealed to the pilot when he makes a longitudinal correction to reduce the approach path angle. Instead of getting the expected response to his control he will, in fact, reduce his speed further and the rate of descent will increase, often with

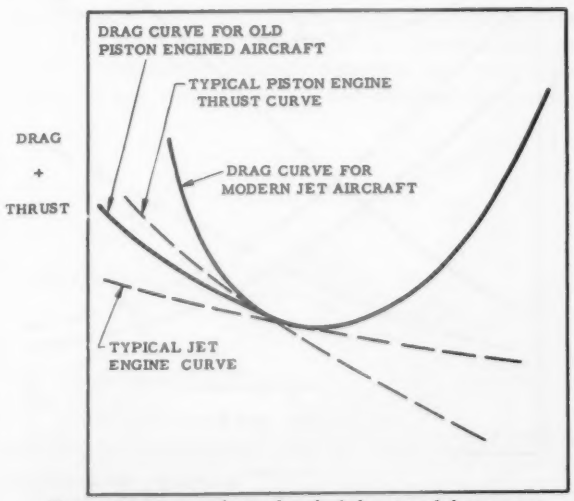

DRAG CURVE FOR OLD PISTON ENGINED AIRCRAFT
TYPICAL PISTON ENGINE THRUST CURVE
DRAG + THRUST
DRAG CURVE FOR MODERN JET AIRCRAFT
TYPICAL JET ENGINE CURVE

FIGURE 10. Comparison of typical thrust and drag curves.

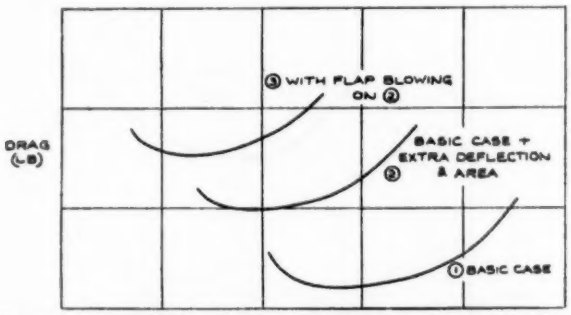
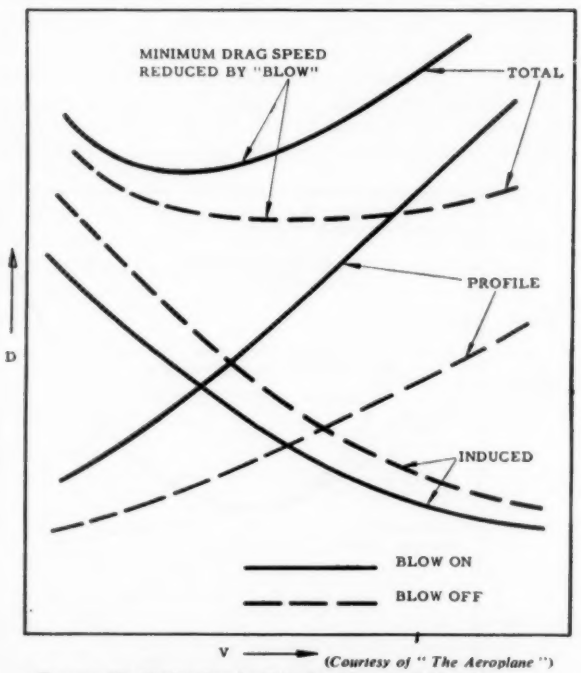


FIGURE 11. Typical variation of drag with changes in flap design and flap blowing and resulting effect on approach speed.

disastrous results. This can be regarded as "speed instability" and is made much worse with modern swept jet aircraft where the divergence of the thrust and drag curves is much more rapid at low speed than on straight-wing piston-engined aircraft and also where large increases in induced drag are resulting from the very low aspect ratios now employed. (*See* Fig. 10.)

If a satisfactory deck landing is to be made it is clearly imperative that there be no speed stability problem. This feature is in fact the limiting condition for the minimum safe approach speed for most modern deck landing aircraft and also, for very many shore-based aircraft. In the case of the Scimitar aircraft modification action to increase the overall profile drag subsequent to the first deck landing trials, where considerable speed stability problems were encountered, resulted in reductions in approach speed. (*See* Fig. 11.)

Most aircraft, and the English Electric Lightning is a good example, use an approach speed far in excess of that at which any stalling characteristics are present,



(*Courtesy of "The Aeroplane"*)

FIGURE 12. Reduction in Vi_{md} by the use of blowing.

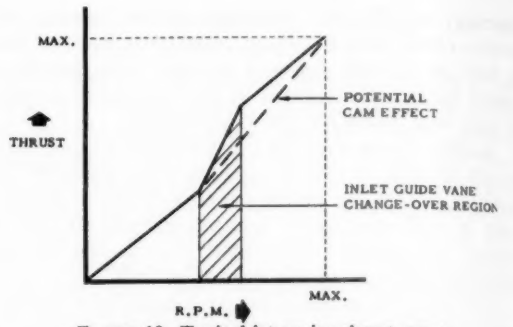


FIGURE 13. Typical jet engine thrust curve.

because of the early onset of Vi_{md} problems, accentuated by the low flap and air brake drag present.

A low indicated air speed corresponding to Vi_{md} is achieved by the combination of a low induced and high profile drag. The use of super-circulation on boundary layer blowing facilities helps this concept. (Fig. 12.)

This concept is also in line with the requirement for high engine r.p.m. on the approach for good response or "blow" requirements. The drag to achieve this must come from profile and thus the need for large air brakes in such aircraft today is paramount.

The requirement to have low induced drag also benefits take-off, *i.e.* better acceleration from a larger thrust/drag differential.

The amazing thing about the whole minimum drag speed, or speed/height stability, problem is that its relevance to current aircraft shapes has only relatively recently been realised. It is one of extreme technical simplicity but has a vast effect upon approach handling characteristics and was at one time confused with the onset of stalling on wing flow breakaway conditions. For example, in some American naval aircraft the profile drag was increased to enable higher and more usable engine r.p.m. bracket to become necessary on the approach and as a result, purely fortuitously, the unpleasant previous characteristics of "sinking on the approach" disappeared.

13. Throttle Sensitivity and Thrust Response

This is particularly relevant to the previous section as the thrust response for a given throttle movement has an important effect on the ability of a pilot to control his air speed or height.

A typical axial flow jet engine thrust curve could be similar to that illustrated in Fig. 13.

Any change in slope occurring in the normal approach r.p.m. band is detrimental to accuracy and aggravating to a pilot. Too steep a slope will produce an over-sensitive throttle response. Too shallow a slope produces excessive throttle movement and an insecure sensation of a lack of thrust. A cam can be used to even out the throttle/thrust response relationship.

14. Approach Incidence and View

On modern aircraft with low aspect and thickness/chord ratios the slope of the lift curve is low. (Fig. 14.)

This leads to very high incidence when approaching to land and gives rise to several special problems.

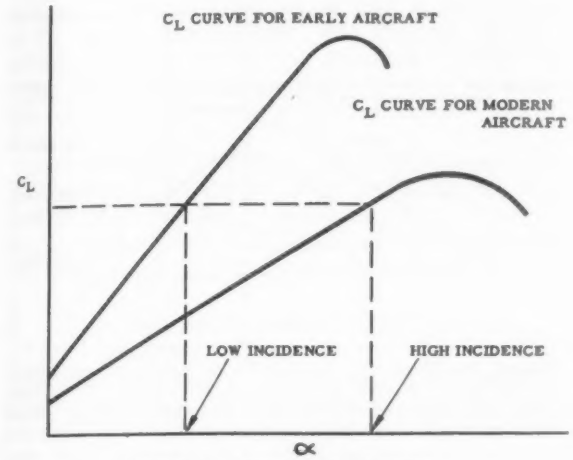


FIGURE 14. Comparative lift curves.

A tail or jet pipe may strike the runway or deck considerably before the main wheels, which can limit the minimum safe approach speed. This is particularly serious on highly swept delta aircraft with central jet pipes and it is difficult to get over this problem.

The standard of view from the cockpit of a naval aircraft must be almost perfect if it is to be operated safely and efficiently from a carrier. High incidences aggravate this point greatly and considerable attention to detail must be maintained during initial cockpit design and right through the development period, if a satisfactory standard is to be reached. These points are obvious but are all too often overlooked when examining the shapely lines and up-to-date devices of a new design.

It is interesting to note that the change of incidence in earlier naval fighter aircraft when rotating from the normal flight to the approach to land condition was of the order of 7 degrees. This change of incidence in the new generation of aircraft is in some cases as much as 14 degrees, doubling the incidence problem. (*See* Fig. 15.)

The N.A.39 has the best view of any British naval aircraft in its category, up to the present time, because of good design and having the wing at some 3 degrees incidence to body datum.

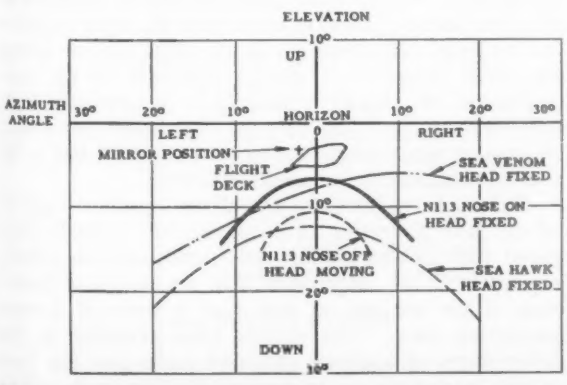


FIGURE 15. Forward view cut-offs in various naval aircraft 1,000 ft. aft of round down.

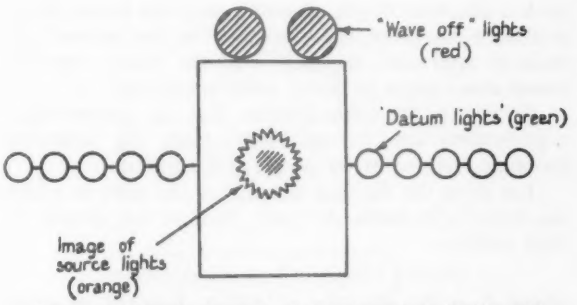


FIGURE 16. Basic elements of the mirror deck-landing aid.

Coupled with this problem of forward view, another, to be discussed later, is the limited view of the deck just before wire pick up.

15. Mirror Landing Aid

The mirror landing sight is at present standard in all American and British carriers. The basic layout is shown in Fig. 16.

The mirror itself is adjustable for height and angle and is gyro-stabilised in one plane. Each ship carries two, one on each side of the deck.

The basic object is to enable the pilot to fly his eye down an accurate eye path such that the aircraft will clear the round down at a safe height and yet place its hook "in among" the wires in an optimum position to pick up one of them. A further requirement associated with this optimum flight path is that the rate of descent of the aircraft should be below certain acceptable maxima.

16. Large Hook-to-Eye Distance

Knowledge of this particular measurement is of great importance when calculating deck landing mirror angles and heights. Its definition is best studied from Fig. 17.

This problem is a direct function of the larger size of aircraft coming into service with the large incidences used on the approach.

The present system of mirror setting calculations involves a given mirror height and beam angle being arrived at to ensure that under optimum conditions the aircraft hook will strike the deck in a known position, usually somewhere between numbers two and three wires. These calculations are also designed to give the

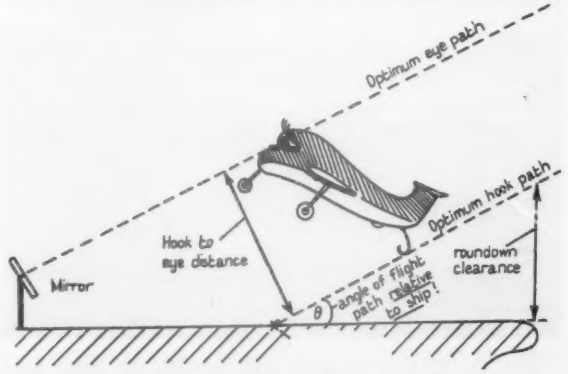


FIGURE 17. Illustrating definition of hook-to-eye distance.

hook a standard height clearance over the round down to allow a margin of safety to cover the low mirror light position approach, together with the worst expected round down pitch in heavy swell conditions.

It may be of some interest that the mirror sight requirements can be calculated from the following formulae, arrived at by simple trigonometry.

Let D be the distance forward of the stern at which the hook is to touch the deck, then in the absence of deck pitch: —

$$D = L - x \tan \alpha + (h - x \sec \alpha) \operatorname{cosec} \alpha$$

where L is the distance of mirror forward of stern, x is the height of mirror centre above deck, h is the hook-to-eye distance (normal to mirror approach path) and α is the mirror beam angle (not approach path).

If a deck pitch correction is desired then, if β=deck pitch angle about the null point, the formula becomes:

$$D = L - [x \tan (\alpha - \beta) + \{h - x \sec (\alpha - \beta)\} \operatorname{cosec} (\alpha - \beta)].$$

During the first deck landing trials aboard H.M.S. *Ark Royal* involving the Scimitar aircraft, the range of mirror vertical movement was found to be inadequate to cope with the large hook-to-eye distance of this aircraft, using the maximum desirable mirror beam angle of 4 degrees with the mirror at its maximum height. Even when holding the mirror light right at the top during the approaches (corresponding to a beam angle of approximately $4\frac{3}{4}$ degrees) the aircraft hook struck the deck 120 ft. before the first wire.

Following this first trial, the mirror height in this ship was raised. Subsequently further modification to all carriers to double the range of vertical movement on their mirrors took place to enable them to cope with the full range of aircraft expected in service over the next few years with their widely differing hook-to-eye distance.

Following on from this necessary increase in mirror height and associated with any forward view cut-off due to the nose of the aircraft, there is a considerable reduction in the amount of the deck that can be seen over the nose of the aircraft during a carrier approach. Relative view cut-offs with the head held stationary are

FIGURE 18. Scimitar about to land, showing the round down clearance.

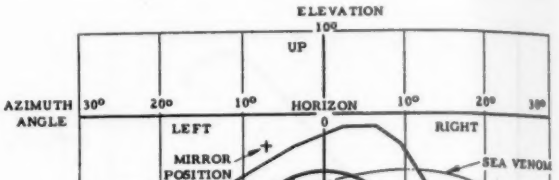


FIGURE 19. Forward view cut-offs in various naval aircraft shortly before touch-down, with aircraft 100 ft. aft of round down. Sea Hawk and Sea Venom at 7° and N113 at $14\frac{1}{2}$° datum relative to flight path.

compared in pictorial form in Fig. 19. This loss of carrier deck view ahead will prejudice accurate line-up down the centre line and may constitute an additional danger, particularly during night deck landings.

One final practical point relevant to this problem is that with current naval aircraft of *small* hook-to-eye distances, experienced deck-landing pilots can make successful carrier landings without the aid of, or without reference to, the mirror. This is because judgment of hook position relative to the deck is much easier when a line from the pilot's eye subtended to the hook path line is small. With larger aircraft of high approach incidence, however, this distance is much greater and the sense of remoteness of the pilot from the back-end of the aircraft makes accurate estimation of relative hook position extremely difficult. This is further aggravated, at the present, by the reduced view of the deck ahead, thus, on deck landing this type of aircraft an implicit adherence to correct mirror light indications is imperative and in the event of mirror failure the landing will be very hazardous.

17. Pilot's Reaction Time

The human physiological problems associated with the retention of an image on the retina of the eye of approximately a tenth of a second, together with the delay in muscular reaction to a given visual stimulus (particularly when mental assessment of a situation is required before a decision concerning the right reaction can be given) constitutes a considerable problem during the latter stages of a carrier approach in the new generation of aircraft which have a relatively high approach speed. This can be aggravated if a fair proportion of the total viewing time available has to be used in watching the air speed indicator.

Although the increase in relative approach speeds of the next generation of naval aircraft is small compared with current aircraft, this trend must be halted, regardless of any improvement in arrester gear limitation, if we are not to arrive at a form of human perception limit. The shorter time available in the latter stages of a carrier approach mean that few last-minute corrections can be made to the flight path. Thus a rather longer straightaway than is current must be

used in such aircraft to enable the pilot to settle down on the mirror approach path with the right throttle settings and speed indications. Accurate maintenance of the correct mirror light indications must be made right up to the touch down point if any repeated degree of success is to be made.

Such comments, of course, have usually been made about most new aircraft in naval service but are now more pertinent than ever because of the greater difficulties of accurate flight path control associated primarily with swept wings.

18. Reduction in Range of Touch-down Speeds

In most earlier and current aircraft of basically straight wing design the fundamental limit to the minimum usable carrier approach speed was the true stall itself, the characteristics of which were usually reasonably clear cut with some possible pre-stall warning in the form of buffet. Thus the usable speed bracket between this and the arrester gear limitations was fairly large and a relatively wide range of approach speeds could be used with satisfactory results without any problems of handling or reaching the limits of the gear.

In high performance aircraft basically of swept-wing design, however, their higher optimum approach speeds are very close to the present arrester gear limits and indeed the minimum desirable relative wind speed may not be attainable in some carriers when operating in zero wind conditions. Such solutions as extending the pull-out of the wires do not provide an answer as the problem is one of initial snatch-loading at the junction of hook and wire.

The definition of the true stall in swept-wing aircraft tends to become rather vague as problems of loss of aileron control and longitudinal instability assume importance; these effects are due to the initial air flow breakaway from the wing tip and occur well before complete flow breakaway from the wing results in the

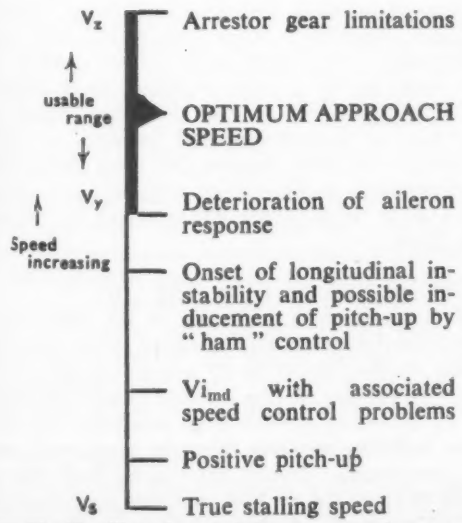


FIGURE 20. Handling characteristics now sometimes present in modern naval aircraft in the speel bracket V_s to V_z.

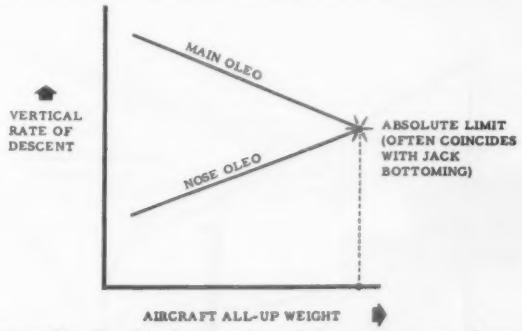


FIGURE 21. Graphical expression of the exchange rate between rate of descent and weight of both main and nose wheel oleos.

absolute stall in accordance with the normally accepted understanding of the definition.

In addition, the further problem of speed instability, associated with flight below Vi_{md}, may well occur at a speed well above the true stall.

Thus all these factors occurring well before the stall will raise the minimum desirable approach speed considerably above the designed true stalling speed. A diagrammatic illlustration of the normal sequence of events may clarify this.

As Fig. 20 indicates, the usable speed bracket may well have been reduced from an original possible maximum of $(V_z - V_s)$ to $(V_z - V_y)$. If the recommended optimum approach speed is selected to be midway between V_y and V_z, then the maximum permissible errors in speed control on either side of this optimum may be as small as two knots.

19. Undercarriage Strength

The main undercarriage strength characteristics are moderately clear cut and are expressed in terms of a vertical velocity and aircraft all-up weight. There is, of course, the normal exchange rate between the two, shown in Fig. 21. Most main undercarriages today are designed for a maximum vertical velocity of 18 ft./sec. at the normal landing weight. It must be remembered that the vertical velocity of an aircraft itself is primarily a direct function of its forward speed and approach path angle. To this, however, must be added the effects of ship motion and last minute corrective action by the pilot, both of which can add considerably to the normal rate of descent.

The nose undercarriage case is further complicated by the exact sequence of events before it touches the deck, *i.e.* the following factors: hook engagement, mainwheel touch, and inducement of aircraft longitudinal rotation by pilot.

These, depending upon their particular sequence, can increase the vertical velocity of the nosewheel considerably above that of the mainwheels and can produce what is now referred to as the nosewheel "slam" problem.

PART II

20. Club Wing (Leading-Edge Extension—*see* Fig. 22)

This is the name given to an extension to the outboard section of the leading edge of several swept-wing

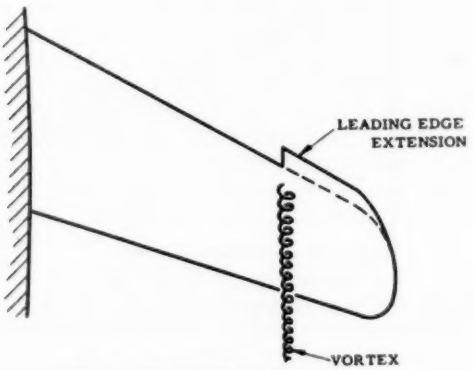


FIGURE 22. Leading edge extension.

aircraft, notable examples being the Swift Mks. 5 and 7, the Crusader and the Scimitar. The effect of this extension is to delay the air flow breakaway from the wing tip which occurs in swept-wing aircraft at high incidence, thus presenting the marked changes in centre of pressure movement resulting in the well known pitch-up and associated longitudinal instability.

The exact aerodynamical details of the improvement are too complicated to go into here, but other improvements result from the following: —

(*a*) The junction of the extension and the normal leading edge produces a vortex which acts like an aerodynamic fence.

(*b*) The decrease in thickness chord ratio over the extension improves wing efficiency.

(*c*) There is an overall increase in wing area, hence improvement in lift characteristics, which will affect approach speed advantageously, manoeuvre boundaries, load-carrying capacity, and so on.

This device has been normally applied to an aircraft as a palliative, subsequent to crystallisation of the original design.

21. Drooped Wing Leading Edge (Fig. 23)

FIGURE 23. Leading edge droop.

This is a feature which can be built into an aircraft wing structure, particularly in the outboard sections as in the Sea Vixen, as a normal fixed condition, or it can be applied when lowering flaps in the approach configuration, as is found on the F8U Crusader and Scimitar aircraft. The purpose is to assist the air flow to adhere to the top surface of the wing at the high wing incidences used during the approach to land in such aircraft, thus delaying the onset of leading edge air flow breakaway which would normally occur under these conditions if no nose droop were present. Thus the use of a lower approach speed than would otherwise be feasible is made possible.

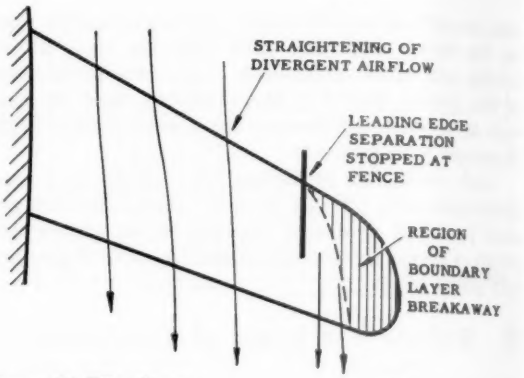


FIGURE 24. Wing fence

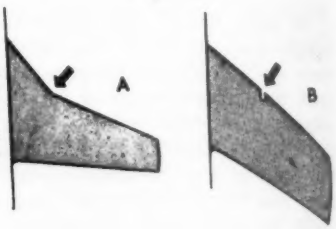


FIGURE 25. Two basic forms of leading edge discontinuity. The Victor and N.A.39 are examples of (*A*); the P.1 of (*B*).

22. Wing Fence (Fig. 24) and Discontinuity in Leading Edge (Fig. 25)

This is a well known palliative that has been applied to a large number of swept-wing aircraft, notably the Sea Venom, Sea Vixen, Scimitar, Cougar and MIG 19. Its position on the wing is often allied with both club wing extensions and leading edge droop.

The function of the wing fence is two-fold; first it has the effect of straightening out the tendency for outward divergence of the air flow, thus alleviating many of the resultant bad features associated with this divergence. In addition, should leading edge separation of the air flow occur on the wing tip, then the presence of a fence has the effect of preventing this separation from continuing along the wing until a much higher incidence than would otherwise be possible has been obtained. The centre of pressure movement and hence onset of longitudinal instability is thus kept within more controllable limits. The ideal palliative to combat this feature would be for a series of fences to be fitted at intervals along the semi-span of the wing; indeed, the MIG 19 has two on each wing half, but drag and buffet considerations normally prevent this from being done.

Discontinuities in the leading edge act in a similar way to a fence, with vortice effects acting as an aerodynamic fence.

23. Double-Slotted Flap (Fig. 26)

With wings at high incidence of the order of 15 degrees to the flight path, flap extension up to 75 degrees will bring the flap chord to 90 degrees to the relative air flow. To prevent air flow breakaway and consequent loss of C_L occurring at such large incidence as well as excessive buffeting resulting from the breakaway itself, certain aerodynamic devices have to be built into the flap itself to make the air flow smoothly over the upper surface of the flap. A device known as the double-slotted flap has been tried with great success on the

FIGURE 26. Effect of double-slotted flap.

Supermarine 525 and subsequently on the early prototype Scimitar aircraft.

The principles involved are those of the well-known wing leading edge slots that have been built into many early aircraft. When lowered, the gap between the flap leading edge and the wing trailing edge constitutes one slot and a further slot is built into the flap itself a short distance behind its leading edge. The function of this device in Scimitar aircraft, although successful, has been superseded by flap blowing.

24. Aileron Droop or Full-Span Flap

This is a device used in the Crusader and N.A.39 aircraft and is really just a means of using all the trailing edge as a flapped surface while retaining conventional aileron facilities.

This device produces high aileron drag factors when drooped and when used as ailerons tends to limit rolling power due to adverse yaw effects. This situation can then be further aggravated by the fact that in addition to aileron drag penalties the use of substantial aileron droop can double the roll with yaw (l_v) effect. To counteract this l_v effect the use of anhedral may have to be adopted to give this a positive value and thus assist the turn.

Another palliative for aileron drag effects, at present adopted in the Crusader aircraft, is the integration of rudder and aileron movement by electronic or direct means. This is a complicated device which carries a considerable weight penalty. In addition, it is wise not to forget that in aircraft with high fins, the use of rudder may in itself produce an adverse rolling moment.

25. Spoilers

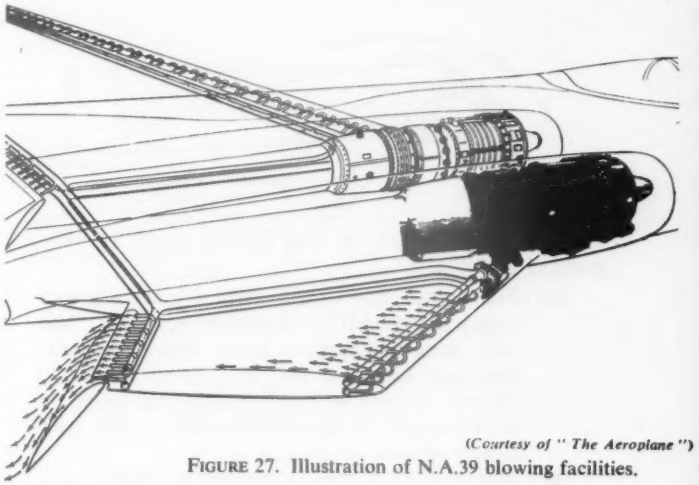
It becomes apparent that if some of the previously mentioned "C_L augmentation" devices are adopted, the high standard of lateral control necessary on naval aircraft in the approach configuration will have to come from other means than the use of aileron alone.

Asymmetric wing, wing tip or tailplane twist, are obvious answers but too complicated for large aircraft, although highly suitable for guided weapon control.

The only other successful approach is by use of the spoiler. These literally destroy lift and, as a result, may alter the aircraft's flight path and the turbulent wake may tend to have further penalties. Nevertheless, on the latest American naval aircraft notably those manufactured by Grumman, the use of spoilers has proved very satisfactory for lateral control, particularly when used in conjunction with the more conventional ailerons.

26. Flap Blowing

With a normal flap system on a thin wing, ultimate separation of the boundary layer and flow breakaway at the larger deflections—even on a flap of the double-slotted variety—cannot be avoided. Thus the potential



(Courtesy of "The Aeroplane")

FIGURE 27. Illustration of N.A.39 blowing facilities.

high lift coefficient and, in consequence lower flying speeds, that might be associated with the larger flap angles cannot be attained. As is well known, such a state of separation exists because the boundary layer has lost much of its energy as a result of frictional losses which become more severe as the angle through which the air flow is expected to deflect is increased. The only way to restore the situation is to put back the energy that has disappeared and this can be done either by blowing high-energy air next to the surface, or by sucking away the low-energy air next to the surface.

In the case of the blown flap it is the first of these two solutions that has been utilised. A high pressure subsidiary air flow is passed over the top surface of the flap from a slot near its leading edge. By this means at high angles of attack and large flap deflections, the separation of the air flow over the flap is prevented and its full potential as a high lift device realised.

The air supply is provided by tapping high pressure air from the engine compressors and ducting this air to the trailing edge of the wing. A "cross feed" system is incorporated so that there is no chance of the blowing occurring on one side only and also, to cater for the single-engine approach (in multi-engined aircraft).

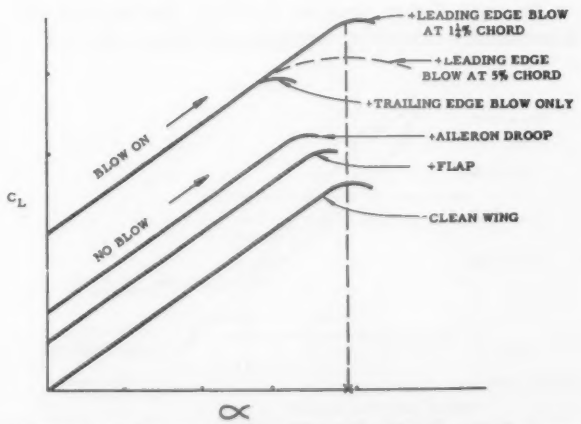


FIGURE 28. Progressive increase in C_L benefits by the more universal use of blowing facilities.

FIGURE 29.

The overall effects of flap blowing may be summarised as follows: —

(*a*) For a given flap deflection at a given angle of attack the overall lift coefficient is higher. Not only does this mean a better slow-speed performance but also, that at a given speed the aircraft attitude will be less nose-up, hence an improvement in the problems associated with high incidence.

(*b*) The maximum lift coefficient is higher with blow on and consequently a lower stalling speed is attainable.

(*c*) As a secondary effect both control and stability of the aircraft at low speeds are likely to be improved by reason of the smoother wake and more stable air flow over the trailing edge of the wing as a whole.

(*d*) A particularly important contribution made by the blown flap is its effect on the aircraft minimum drag speed (Vi_{md}). Depending on the particular application, with the blown flap in operation, the overall induced drag may be decreased a small amount while there is a considerable increase in the total profile drag. (*See* Fig. 12.) This is the case with the Scimitar aircraft and means that Vi_{md} is much lower than before. Thus, in addition to decreasing stalling speeds *per se*, the blown flap system enables lower approach speeds to be used.

The use of flap blowing can be extended to other parts of the wing or tail surface with benefit.

The use of blow on the leading edge acts in a similar manner to leading edge droop and there is an optimum position dependant upon top surface curvature, normally of the order of one per cent chord.

An even better position is at the junction of the discontinuity caused by leading edge droop (Fig. 29).

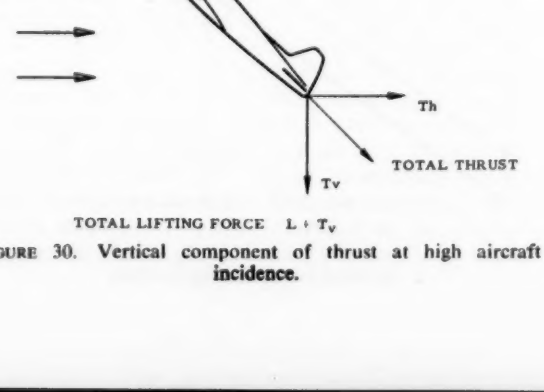


FIGURE 30. Vertical component of thrust at high aircraft incidence.

27. Deflected Thrust

In aircraft which approach at high incidence, the contribution to the overall lift by the vertical component of the thrust, is considerable.

Thus the usable lift coefficient of the wing can be augmented by this thrust component and a slight reduction in approach speed obtained. Further use can be made of this beneficial effect if the thrust line is deflected by rotating the end of the jet pipe itself. Such a device has received considerable flight investigation in this country in a specially modified Meteor with two Nene engines. It has been flown by R.A.E. Farnborough and subsequently, R.A.E. Bedford. The success of such a modification depends primarily on having a large thrust/weight ratio available initially so that the maximum desirable jet deflection angle can be used while still retaining a sufficiently large horizontal thrust component for good speed and flight path control, bearing in mind also the need for sufficient thrust for over-shooting.

This device has not yet been adopted on naval aircraft but was contemplated for the now cancelled Saunders Roe 177, mixed-thrust interceptor fighter.

As previously stated, at the high incidences being used, the vertical component of thrust is relatively high even with conventional thrust lines and thus some benefits to lift are being felt. (*See* Fig. 30.)

28. Variable Incidence Wing

A remarkable practical example of the variable incidence wing is to be seen on the F8U Crusader. Its purpose is to alleviate all the problems encountered with high incidence enumerated previously. Thus, problems of view, the possibility of striking the back-end of the aircraft on landing, loss of direction stability at high incidence and all the problems associated with large hook-to-eye distance, are solved by this device. When about to enter the approach configuration the wing incidence relative to fuselage datum is increased by merely pushing the wing leading edge away from the fuselage by a hydraulic jack.

The effect in the air is merely for the fuselage to rotate in the nose-down sense relative to a wing which remains at approximately constant incidence to the relative air flow. The advantages enumerated from the approach point of view have been dealt with and need no further amplification.

In addition, however, there is a take-off advantage inasmuch as the wing is already at the optimum incidence and thus no large rotation of the fuselage is required to achieve the best conditions for either a free or catapulted take-off.

29. Drooped Snoot

The most startling example of the dropped snoot is the well-known Fairey Delta 2. The whole nose of the aircraft forward of the pilot can be made to cant downwards mechanically under control of the pilot. The advantage is obvious, being one of a considerable increase in forward view for the landing approach. Delta aircraft suffer from poor view associated with their high incidence when approaching to land.

Generally the weight penalty of such a device would preclude its use in normal production aircraft.

30. Vertical Take-Off and Landing

V.T.O.L. only becomes possible with aircraft whose total engine thrust exceeds their take-off weight by an appreciable margin. Current successful examples of this principle are to be found in the American Convair "Pogo" and the Ryan X.13 Vertijet; the principle has been tackled in rather a different manner by the British Short S.C.1.

Problems of wing design to overcome the low-speed approach problem are eliminated by this concept, only to be replaced by the more severe problems of transition from level to vertical flight in the case of the American aircraft. In addition, the inability of the pilot to see along his vertical descent path will bring about problems of positioning the aircraft accurately on the correct touch-down point. Although none of these problems are insurmountable, it is felt that the engineering devices which will have to be built into these aircraft for accurate pilot-controlled approach may well impose performance penalties which will preclude the use of such aircraft in the high-performance interceptor role.

31. Auto-Stabilisers

The use of auto-stability functions on at least two out of the three basic aircraft axes is now being adopted more and more to bolster up mediocre lateral and directional stability in the approach configuration, rendered unavoidable by other aerodynamic requirements.

The use of this device has now been generally accepted to the extent that duplication of such facilities is now deemed a positive requirement. The subject of auto-stabilisers is a study complicated enough to warrant further discussion outside the limits of this paper.

Primarily, rotation of the aircraft about a particular axis is sensed by displacement relative to a gyro and the information transcribed electronically into a corrective movement to the appropriate control surface. Response is normally allied to rate of displacement or (rate of displacement)^2 and if no d.c. blockage facility is fed into the electronics, control displacement can remain, at a constant rate of rotation. This latter state gives a semi-auto-pilot function by a virtual sense of "position in space" and can be used to some advantage for the rolling function, particularly in bumpy air conditions with aircraft of high l_r or l_p characteristics.

Negative phase advance terms can sometimes be fed in with advantage to speed rate of damping, although the amplitude of initial deflection may increase.

It must not be forgotten that the use of artificial stability has one basic penalty, that is opposition to pilot control about the same axis as the auto-stability itself is responding, *i.e.* the unit will fight the aircraft movement that the pilot is trying to induce.

Thus a compromise has to be adopted between control and stability, which can often be expressed in terms of control gearing (as shown in Fig. 31).

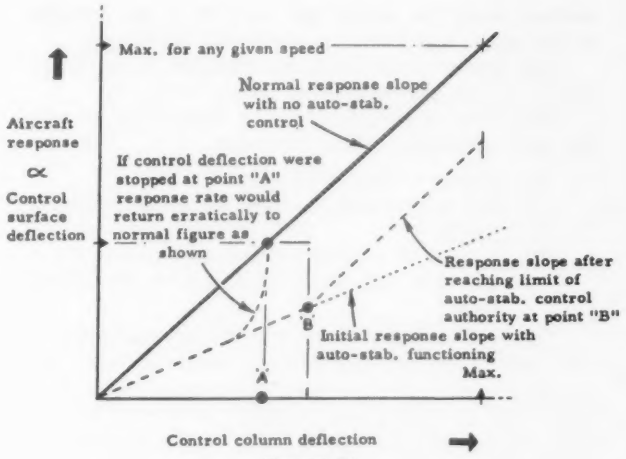

Max. for any given speed
Normal response slope with no auto-stab. control
Aircraft response ∝ Control surface deflection
If control deflection were stopped at point "A" response rate would return erratically to normal figure as shown
Response slope after reaching limit of auto-stab. control authority at point "B"
Initial response slope with auto-stab. functioning Max.
A
B
Control column deflection

FIGURE 31.

32. Audio Air Speed Indicator

The principle of the Audio air speed indicator is to give the pilot aural indication of his air speed over an appreciable band on either side of the desired optimum, thus relieving him of the necessity to look at his A.S.I. during the final stages of carrier approach. Therefore, full visual effort can be concentrated on the view of the intended landing area and mirror light indications with, consequently, a more immediate physiological response to a required change in the aircraft's approach path. This device will be invaluable in future aircraft with their higher relative approach speeds and problems mentioned in Section 17.

The Audio A.S.I. has taken two forms, the first of which may be familiar to many pilots as the device was fitted for a trial period to some Squadron Wyvern and Venom aircraft. That particular version took pressure differential information from Pitot and static sources in a similar manner to the conventional A.S.I. and electronically transcribed this data to produce a noise in the headphones, related to indicated air speed. The noise indications and their relevance to the optimum air speed are best studied from Fig. 32.

The optimum air speed can be arranged to occur

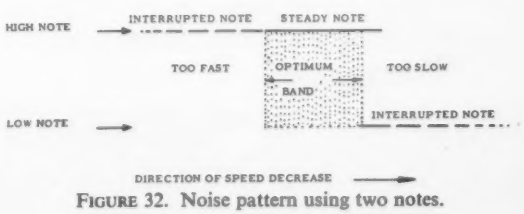


FIGURE 32. Noise pattern using two notes.

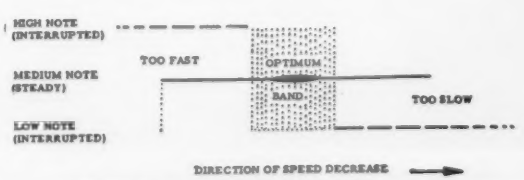


FIGURE 33. Noise pattern using three notes.

midway along the steady high note or at the junction of the steady high and the interrupted low note.

This type of presentation can be aided by the introduction of yet another note as shown in Fig. 33.

Whichever method is used the objects are to give the pilot indications of the following: —

(*i*) vicinity to the optimum speed
(*ii*) rate of approach to or away from the optimum speed
(*iii*) a band of optimum speed indications of not less than two knots each side of the desired figure.

This type of Audio A.S.I. was of great value during the early Scimitar deck landing trials but was not sensitive to incidence, therefore, the optimum indications were only correct at one weight. It was, therefore, also of little value in turns on to the final approach and suffered from excessive sensitivity in bumpy air.

33. Incidence Indicators

The use of these indicators has now assumed more importance as a visual indicator, with or without audio indication as well. The main reasons are the greater importance of Vi_{md} problems in aircraft of low thrust/weight ratios when being catapulted.

These problems have been experienced by Venom aircraft—in particular at night or in conditions of no horizon where the pilot lacks the instrument information to maintain the correct incidence.

The measurement devices necessary for constant incidence attainment have taken three basic forms: —

(*i*) probe with two slots; probe rotates until pressure in the slots is equalised
(*ii*) small vane at $0{\cdot}020C$, lightly spring-loaded senses direction of flow near stagnation point
(*iii*) capsules ratio Pitot pressure/underwing pressure at $0{\cdot}1C$, *i.e.* measures pressure variation associated with movement of the stagnation point.

These indicators are currently undergoing an intensive period of development at Ministry of Aviation flight development centres and Aircraft firms, during which various forms of visual and aural presentations are being evaluated. The present trend is that their use will become more universal than hitherto and their various facilities accepted as a normal aid to all forms of flying.

FIGURE 34. The point subsequent to catapult launch at which maintenance of accurate optimum incidence becomes critical.

34. Auto-Throttle Control

This is an electronic device which, taking its information concerning air speed or wing incidence in the same manner as the Audio A.S.I., can be made to increase engine r.p.m. automatically as speed is reduced below that corresponding to Vi_{md} to compensate for the subsequent increase in induced drag. Thus, provided no other low-speed approach problems occur, the speed on the approach can be steadily reduced to a figure considerably below that corresponding to Vi_{md} without the throttle juggling which normally results when a pilot endeavours to cope with the speed stability problem in this region.

This device received considerable early investigation fitted to an Avro 707 and it is possible that it will be fitted to the Avro Vulcan as Vi_{md} problems are prevalent in all delta aircraft, probably more so than on current swept-wing aircraft.

More recent work at the R.A.E., Bedford, has produced encouraging results of this device when fitted to both Scimitar and Sea Vixen aircraft.

Similar evaluations on later naval prototypes are expected to reveal considerable similar benefits.

35. Tailplane Position

As mentioned in the section on "Pre-stall longitudinal instability," tailplane position is the biggest single factor, other than sweepback/aspect ratio combination, affecting pitch-up at high lift coefficient due to the de-stabilising effect of the increased downwash with

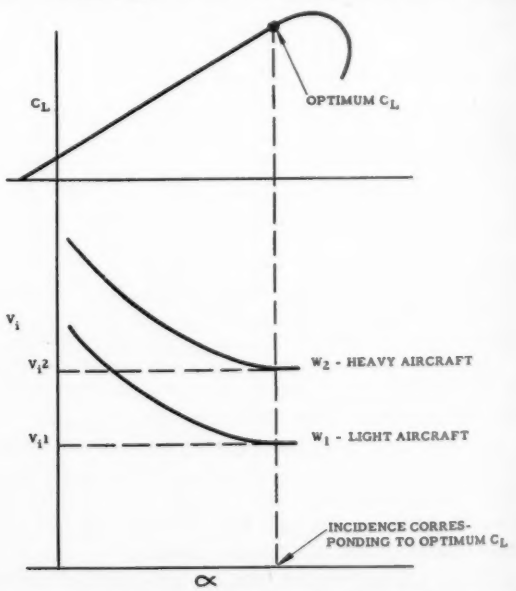


FIGURE 35. Illustrating constant incidence requirement for optimum C_L attainment at all aircraft weights.

FIGURE 36. Change in downwash effect with increase in incidence.

increase in wing incidence. In actual fact, it would be more correct to say that the rate of change of downwash affecting the tailplane with increase in wing incidence is the most important factor affecting stability.

Figure 36 attempts to show the change of downwash effect on three possible tailplane positions at two different wing incidences.

Current investigations into this matter have revealed that the rate of change of downwash for a high-set tailplane is considerably worse than that for low-set tailplane positions, hence the current trend for the adoption of the latter when other reasons of proximity to jet efflux do not prevent it. For those who are graphically minded, Fig. 37 may be of interest. When plotting tailplane downwash angle (ξ) against wing incidence (α) a graph can be produced for different tailplane positions.

If we take the increment ($d\xi/d\alpha$) for normal stable aircraft with low-set tailplane this roughly equals one half. Now, with some modern configurations using high-set tailplane, this value approaches unity at high wing incidences and stability problems are present.

In Fig. 38 the ξ/α curve ⊙ solid lines show downwash at tailplane with attached wing flow of constant type. Dotted lines show the effect of unsupressed wing flow change which can increase ($d\xi/d\alpha$), giving sharp fall off in tailplane stabilising power. If this wing flow effect can be suppressed (blow) a high tail will be effective.

If not suppressed, a low tail, which will be below the region in which the rapid change of downwash occurs, will be necessary.

36. Tailplane Flap and Blow

The previously mentioned possibility of having to have large negative tailplane extensions during an approach, to overcome the pitching moment of C_L augmentation wing devices, can be overcome by the use of a tailplane flap.

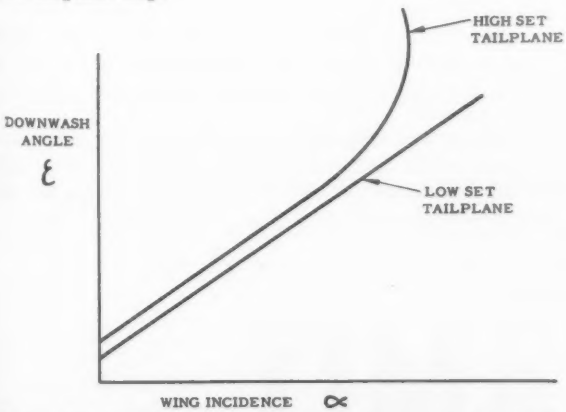


FIGURE 37. Graphical presentation of change of downwash angle for two different tailplane positions.

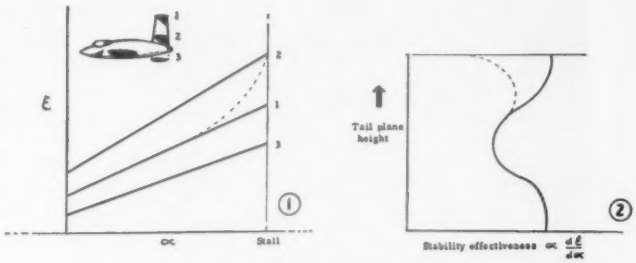


FIGURE 38.

The improvements are apparent from Fig. 39, including the further benefits of blowing on the leading edge.

Further improvements to basic tailplane effectiveness result from the reduction of the incidence of the main surface to nearer the zero degree figure. In addition, this condition means that the main surface is further removed from a stalling incidence. Thus potential loss of tailplane effectiveness during a take-off will be avoided.

37. Variable Power Control Gearing

The ratio of control column movement to control deflections—in particular tailplane and ailerons—must be nicely balanced so that a compromise is reached with regard to the conflicting requirements of both ends of the speed band of the aircraft.

Ideally these requirements are: —

(*i*) Low I.A.S. That reasonably large control deflections can be obtained by moderate displacements of the control column as there is a normal loss of control effectiveness at low I.A.S.

(*ii*) High I.A.S. That fairly small control deflections can be obtained by moderate displacements of the control column to prevent undue sensitivity due to the extreme effectiveness of most control surfaces at high I.A.S.

(*iii*) High Mach number. These requirements are similar to low I.A.S. (case (*i*)) as there is normally a fall-off in control effectiveness once the normal shockwave pattern has set in.

These conditions are shown in Fig. 40.

In some aircraft, such as the early Sea Vixen, it was

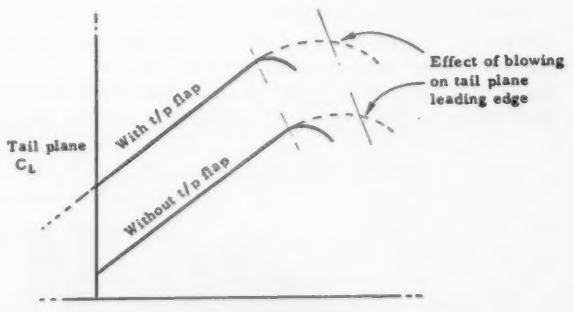


FIGURE 39.

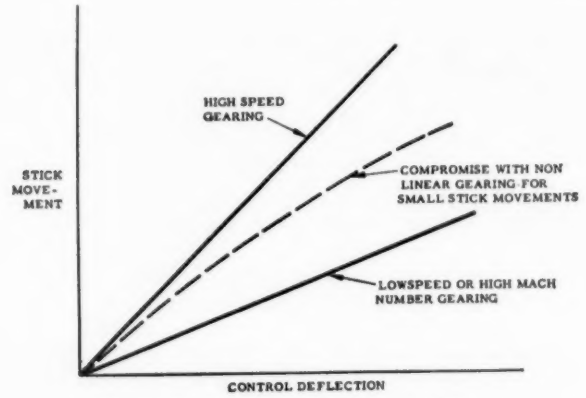

HIGH SPEED GEARING
COMPROMISE WITH NON LINEAR GEARING FOR SMALL STICK MOVEMENTS
LOWSPEED OR HIGH MACH NUMBER GEARING
STICK MOVE-MENT
CONTROL DEFLECTION

FIGURE 40. Basic control gearing diagram.

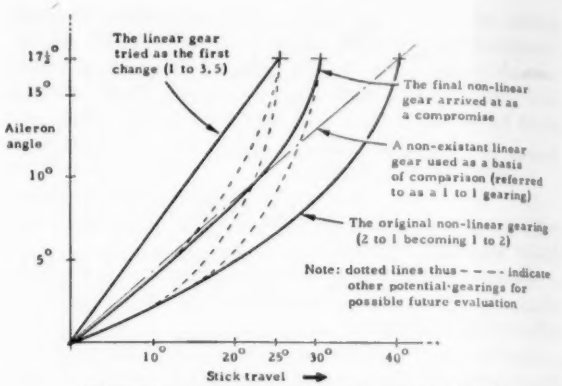

The linear gear tried as the first change (1 to 3.5)
The final non-linear gear arrived at as a compromise
A non-existant linear gear used as a basis of comparison (referred to as a 1 to 1 gearing)
The original non-linear gearing (2 to 1 becoming 1 to 2)
Note: dotted lines thus - - - - indicate other potential gearings for possible future evaluation
Aileron angle
Stick travel

FIGURE 41. Aileron gearing tried on the N.A.39.

found impossible to arrive at a simple compromise in the aileron and tailplane circuits. The aileron gearing was altered manually by a wheel similar to the present system in Sea Venom aircraft. The tailplane circuit had three basic gearings, one for the approach case, another for the normal subsonic speed band range and a further gearing change for supersonic flight, the change-over being controlled by a Mach sensor.

In the Scimitar a satisfactory compromise has been achieved for tailplane operation by arranging the linkage between the control column and tailplane power jack valve to give a non-linear effect over small deflections from the neutral position. The effect of this is also shown in Fig. 40.

Another factor relevant to this problem is to be found in the tailplane of the Sea Vixen, where a "pseudo elevator" is attached at the rear of the tailplane. During normal flight this remains rigid relative to the forward section and to all intents and purposes is part of the slab, but on lowering the undercarriage before entering into the approach configuration, it deflects upwards. As the tailplane has a negative incidence under these conditions, this has the effect of increasing the C_L of the tailplane section in the negative sense. The advantages of such a device can be summarised as follows: —

(*i*) A smaller tailplane can be used—hence a lessening in weight and drag.

(*ii*) A smaller total angular range of tailplane movement is needed.

(*iii*) The trim change associated with entry into the approach configuration can be eliminated.

The adoption of the non-linear linkage gives the best results on tailplane and aileron controls, particularly when a compromise gearing between the low and high speed requirements is being sought. The decision on a final value, however, is always difficult as can be judged from Fig. 41, which shows the various aileron gearings tried and/or contemplated during the N.A.39 flight development programme.

Acknowledgments

Acknowledgment is given to the various people in the Aircraft Industry and the Ministry of Aviation who have helped by discussing various aspects of this paper during its formation and in particular to Mr. Dennis Higton, A.F.R.Ae.S., of the Aircraft and Armament Experimental Establishment, Boscombe Down, without whose early assistance and encouragement the original theme might never have developed to its present gargantuan proportions.

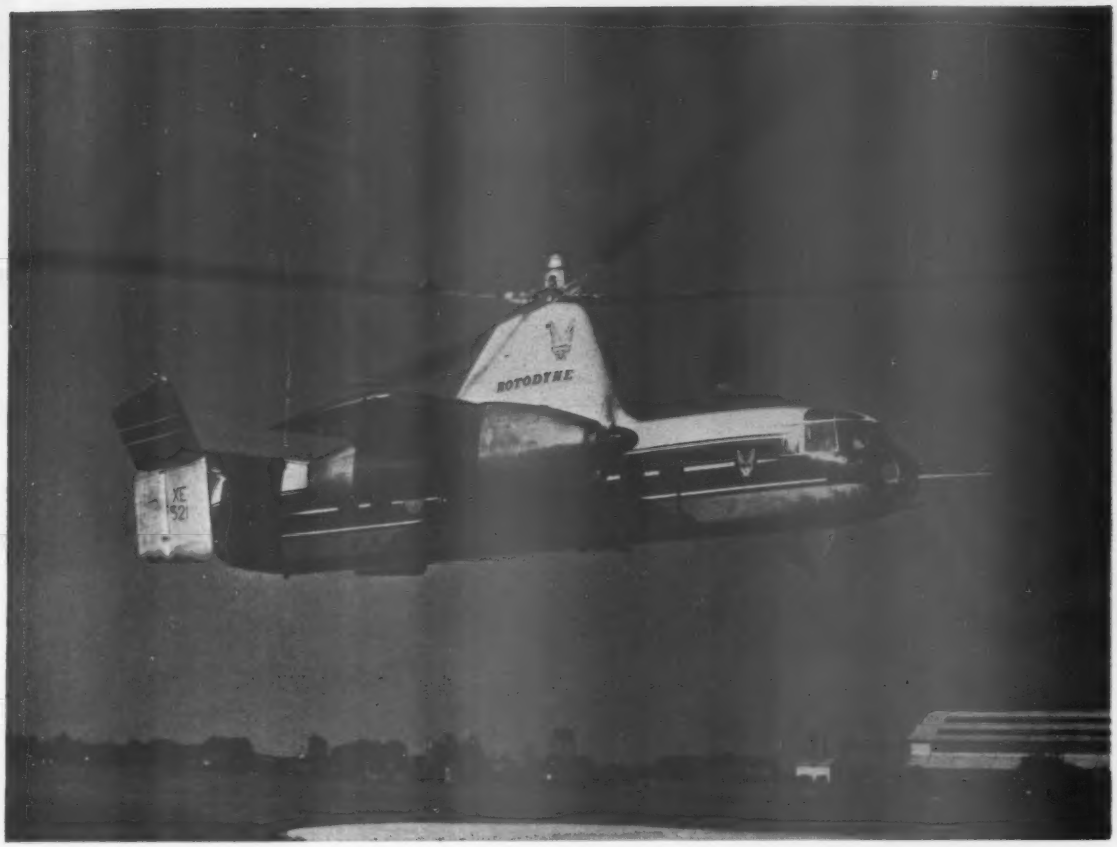
Acknowledgment is given to Vickers-Armstrongs (Aircraft) Ltd. for provision of the majority of the ship and aircraft photographs and to *The Aeroplane and Astronautics* for two of the diagrams.

The author also thanks Vickers-Armstrongs (Aircraft) Ltd., de Havilland Aircraft Ltd. and Blackburn Aircraft Ltd. for permission to publish the relevant information concerning their products.

The majority of the discussion concerns current British naval aircraft flown by the author. Discussion of the problems encountered during their development periods is in no way intended to criticise the efficiency and technical abilities of the well-known parent firms concerned.

The most excellent co-operation was always forthcoming from all these firms during flight evaluation of their products in these extremely interesting development periods.

It must be emphasised that all service aircraft, before delivery to the customer, are at the best standard possible within the limits of the best technical knowledge and constructional skills available in this country today.



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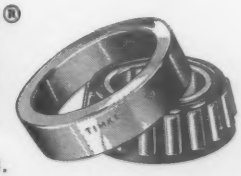

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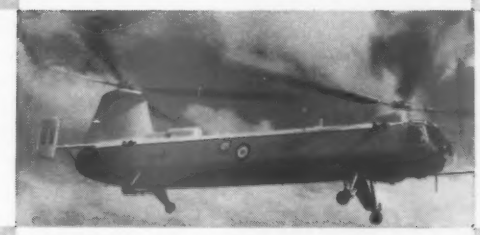

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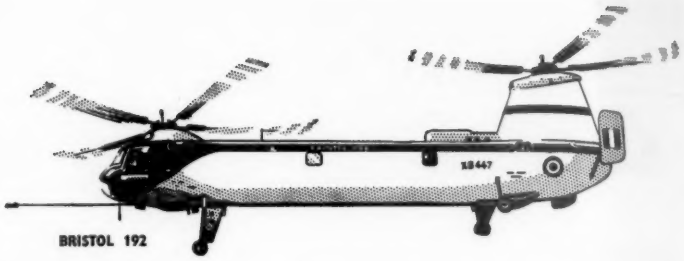

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Vertical Transport Business

by

ROBERT L. CUMMINGS Jr.

(President, New York Airways Inc.)

The first lecture before the Rotorcraft Section of the Society, "Vertical Transport Business" by Robert L. Cummings, Jr., was given on 5th February 1960 at 4 Hamilton Place, London, W.1. Professor J. A. J. Bennett, D.Sc., Ph.D., D.I.C., F.R.Ae.S., Chairman of the Section presided.

Opening the meeting Professor Bennett read a telegram from the President of the Society, Mr. Peter G. Masefield, M.A., F.R.Ae.S., Hon.F.I.A.S., regretting his inability to be present and wishing the Section every success. Introducing the lecturer Professor Bennett said that not only was this the first meeting of the Rotorcraft Section of the Royal Aeronautical Society after the merger with the Helicopter Association, but the whole of the helicopter industry in the United Kingdom had also been merged. The Section extended its good wishes to the Westland Company and to its Chairman, Mr. Eric Mensforth, a Past President of the Helicopter Association, who was responsible to a large extent not only for the success of the Association, but also for the successful formation of the Rotorcraft Section.

After graduating from the University of Harvard in 1935 Mr. Cummings attended Harvard Law School. He joined Pan American World Airways in January 1940, and during the war was engaged in administration of Pan American's contracts for the construction of military airports in Central and South America. At the end of the war he was appointed Manager of the Atlantic Division but left in 1947 to become Deputy Director of the Industry Division of the Economic Co-operation Administration. Since 1952 he had been President and a Director of New York Airways, Inc. He had been active also in the U.S. Air Transport Association and in I.A.T.A.

SUMMARY: Turbine-powered helicopters mark the most important step taken thus far in the transition from *development* to *business* for that segment of the transportation industry which utilises the capability for vertical flight.

Completing more than a year of detailed study and evaluation, New York Airways recently announced its commitment to purchase ten multi-turbine Vertol 107 aircraft designed to cruise in excess of 150 miles per hour with 25 passengers. They will be introduced into service in the spring of 1961. With these machines commercial revenues could, for the first time, offset all operating charges and produce a fair return on the capital investment—without government financial support. The availability of the Fairey Rotodyne in 1964 will place New York Airways in a position to offer the public a substantially enlarged and even more useful service operating on a business basis.

IN THIS the middle of the twentieth century, it is possible to travel between any two large airports in the world within 24 hours. Twenty years ago this same journey could easily consume several days or even stretch into weeks. Today, the United Nations Organization, due in no small part to the modern facility of communication and transportation, has survived many difficult trials and is growing ever stronger and more influential as man's great hope for security and betterment. The impact of the Age of Flight has already been felt in almost every phase of life. Yet this miraculous era has only just begun.

At the moment studies are well advanced which could lead to the production of air liners whose speed will surpass a Mach number of 2 and even Mach 3. From a technical point of view, the attainment of this objective constitutes no insoluble problem. Exactly what engineering specifications will control the ultimate configurations and whether or not, for reasons of overall efficiency, the designers will be compelled to combine the capacity for supersonic speeds with the ability to land and take off vertically, are still moot questions.

However, it must be noted that even now, on relatively short journeys—those up to 300 or 400 miles—the need for increased speed in the air (unless it also includes the ability to fly vertically and therefore to utilise small, conveniently located landing areas) is becoming highly questionable, if not non-existent. For example, in travelling from the centre of New York City to an equivalent place in Washington, using taxi cabs and the most modern fixed wing aeroplane, it is a matter of fact that an individual requires, under optimum circumstances, more than two hours. The actual flight occupies less than half of this time. As compared to this, with an aircraft capable of vertical flight and a forward speed of no more than 250 miles per hour, the trip from the centre of Manhattan to the centre of Washington could be accomplished with great reliability in just about one hour, including five or six minutes at each end for ground transport.

A similar situation exists between cities such as London and Paris, Paris and Brussels, and Tokyo and Kobe. Indeed, as time goes on, there appears to be considerable reason for believing that this condition will develop on even longer routes. The future of the vertical transport business is full of possibilities. What of the present?

New York Airways, the company with which I am associated, carried its first passenger on 8th July 1953. During the year 1959 we carried some 125,000 persons on our route system. By the end of 1963, we expect to be carrying passengers at the rate of 1,000,000 a year.

At present we operate rotary wing aircraft. This type of machine is the only one, capable of vertical flight, which has been sufficiently developed to perform commercial functions. The mission currently being performed by our company is the development of a community centre to community centre airline serving the public in the vicinity of New York City. (The average passenger travels eighteen miles and the average

FIGURE 1. New York Airways' helicopter landing at the 30th Street Heliport on the Hudson River in New York's Manhattan area.

stage length is twelve miles.) To this end we are subsidised. This means that we receive financial assistance from our Government (through the Civil Aeronautics Board) which is based on the excess of our approved operating costs over our earnings from commercial sources. It includes an allowance for taxes and a return on invested capital.

For some time we have forecast that, under conditions where New York Airways' schedules could offer high frequency and obtain high load factors, the operation would become free of subsidy. Up to the present time, with heavy piston engines, that has not been possible, but with the application of turbine power to helicopters, the prospect should, in the not too distant future, become reality.

Figure 2, which is a chart setting forth certain consolidated results of the three United States scheduled helicopter operators, indicates the advances that have been made up to the present in our collective ability to serve the public. It shows, to be sure, that our total subsidy requirement has come close to doubling between the years 1954 and 1959. Nonetheless, at the same time, the number of seat miles produced has multiplied some twenty times, growing from an initial 725,000 a year in 1954 to an approximate 15,000,000 in 1959. Thus, during this period, the subsidy need per unit of passenger service (available seat mile) has been reduced from $3.61 to 32 cents and the percentage of revenues derived from commercial sources has risen from 7 per cent to 35 per cent. Given nothing else, this represents remarkable progress. However, with the delivery of multi-turbine aircraft in 1961, we in New York Airways, at least, are confident that, by the end of 1965, the productivity of these three companies, in terms of seat miles, will have been further increased by no less than four and one-half times and that the collective requirement for subsidy will have been substantially, if not entirely eliminated.

From the outset of operations, New York Airways has considered that it was engaged in the business of flying passengers, mail and property, with a minimum dependence on ground transport, *directly* from their points of origin to their destinations regardless of whether these locations are congested urban centres, surrounding communities, or fixed wing airports. Therefore, for lack of a better definition, we refer to our type of operation as "Direct Service".

Although our business objectives are clear, our planning has had to be flexible. For this reason, so that we could co-ordinate our operations with changing needs, we have kept in close contact with all phases of the transportation industry. We have paid particular attention to the requirements of the travelling public, both in the air and on the surface, and we have been in day-to-day contact with the airframe, engine, and instrument manufacturing industries. The development of more efficient equipment and the resolution of the many questions involving promotional, as well as technical, matters has consumed much of our money, time and energy.

Pending the introduction into service of multi-turbine helicopters with their greater capacity, higher speed and all-weather capability, our operations have been more restricted than might have been expected. Even so, New York Airways has established certain suburban and inter-city schedules and has concentrated much effort on the very short inter-airport and down-town services where we have access to a market which is characterised both by high density and by high revenue yield potential. (Our average fare is 48 cents per seat mile and on one segment the fare is 71 cents per seat mile.) Flying twenty-four hours a day on these routes, in varying weather conditions, has exposed us to many of the problems that will be encountered on a larger scale as the scope of our business is increased. It has given us essential information and "know-how."

The fact that jet aircraft can only be operated efficiently at high altitudes and from airports with long runways has caused us to believe that there will be a growing requirement for a Direct Service type of operation to assist in expediting the collection and distribution of jet passengers and cargo. Many persons who fly the Atlantic in six and a half or seven hours will not be prepared to spend close to three hours

additional time on the ground covering less than one per cent of the total journey distance. Hence, it seems only reasonable to expect that, with improved equipment and additional heliports, New York Airways should be able to perform an increasingly useful function as an adjunct to the long-haul fixed wing aircraft.

Looking a little farther into the future, serious thought has been given to the necessity for an entirely new kind of service created by spreading surface congestion which is currently threatening to throttle many of the larger communities. In spite of heavy expenditures on new highways, ground transportation conditions are getting less and less reliable and more and more difficult.

In New York, this difficulty has given rise to tentative plans for peak hour, high frequency schedules over routes connecting various heliports in the city centre with specially selected landing sites on the outskirts of the heavily populated metropolitan district. These peripheral points would, in all probability, be large automobile parking lots, readily accessible by private car, bus and even railroad. These landing sites couid also be used as transit stops on routes to outlying communities and neighbouring cities.

The possibilities that lie ahead for exploitation by Direct Service are not yet defined and, although the law of supply and demand will ultimately determine the form that this relatively new segment of the transport industry will take, it is obvious that the advent of multi-turbine helicopters will have a most impressive impact.

In recognition of this, based on many hundreds of man hours of intensive study and evaluation, New York Airways has recently made the decision to replace its fleet of single-piston-engine helicopters with multi-turbine Vertol 107 helicopters. This machine, powered by two (or three) General Electric T-58 gas turbine engines, is guaranteed to cruise at 135 knots (155·5 m.p.h.). It is a tandem rotor aircraft carrying 25 passengers.

As indicated in Figs. 3 and 4, we expect to start out with five Vertol 107s and from there on increase the size of the fleet as required. The rate of the build-up will depend primarily on the continuing development of the public demand for our services. Today we are conducting operations with five 15-passenger Vertol 44 helicopters. As a consequence of increased capacity and frequency, as well as improved performance, our available seat miles will immediately be multiplied almost four times. With our present fleet, we produce approximately 5,800,000 seat miles a year. With five Vertol 107s, we will produce about 22,000,000 seat miles a year, and with ten such aircraft we will approximate 55,000,000 seat miles a year. At the same time, it will be observed that our subsidy requirement per available seat mile will descend from 48 cents with the Vertol 44s to 12 cents with an initial fleet of five Vertol 107s.

The curves on Fig. 4 demonstrate that the relationship between our Vertol 107 fleet potential and our total subsidy requirement likewise becomes rapidly more favourable. The financial results and statistical information on which both Figs. 3 and 4 are based are given in the Appendix.

With the improved economics that are projected for the V-107, it is planned that many of New York Airways' present routes will be operated at very high frequency. This would include the elimination of much of the paper work that is now required, and might permit passengers to travel, with complete assurance, without the necessity for making advance reservations. Likewise, during this period arrangements are being

CALENDAR YEAR	REVENUES FROM ALL COMMERCIAL SOURCES	SUBSIDY	GROWTH OF COMMERCIAL REVENUE AS A PERCENTAGE OF TOTAL REVENUE	AVAILABLE SEAT MILES	SUBSIDY PER AVAILABLE SEAT MILE
1954	$184,723	$2,615,000	7%	725,000	$3.61
1955	$392,517	$2,691,000	13%	1,708,000	$1.58
1956	$642,806	$3,150,000	17%	3,561,000	88 cents
1957	$1,203,821	$3,881,000	24%	8,049,000	48 cents
1958	$1,699,791	$4,526,000	27%	11,419,000	40 cents
1959[2]	$2,628,000	$4,868,000	35%	15,000,000	32 cents
1961	INTRODUCTION OF TURBINE POWER				
1965[3]	(a) $15,500,000	*	*	68,000,000	*
	(b) $18,000,000			90,000,000	
	(c) $27,000,000			135,000,000	

FIGURE 2. Productivity. Consolidated results of the three United States scheduled helicopter operators.

NOTES:

1. Chicago Helicopter Airways, Inc., Los Angeles Airways, Inc., New York Airways, Inc.
2. Results for year based on the actual results for eleven months.
3. (*a*) 15 aircraft divided between the three airlines—each aircraft carrying 25 seats at a block speed of 100 m.p.h.
   (*b*) 20 aircraft divided between the three airlines—each aircraft carrying 25 seats at a block speed of 100 m.p.h.
   (*c*) 30 aircraft divided between the three airlines—each aircraft carrying 25 seats at a block speed of 100 m.p.h.

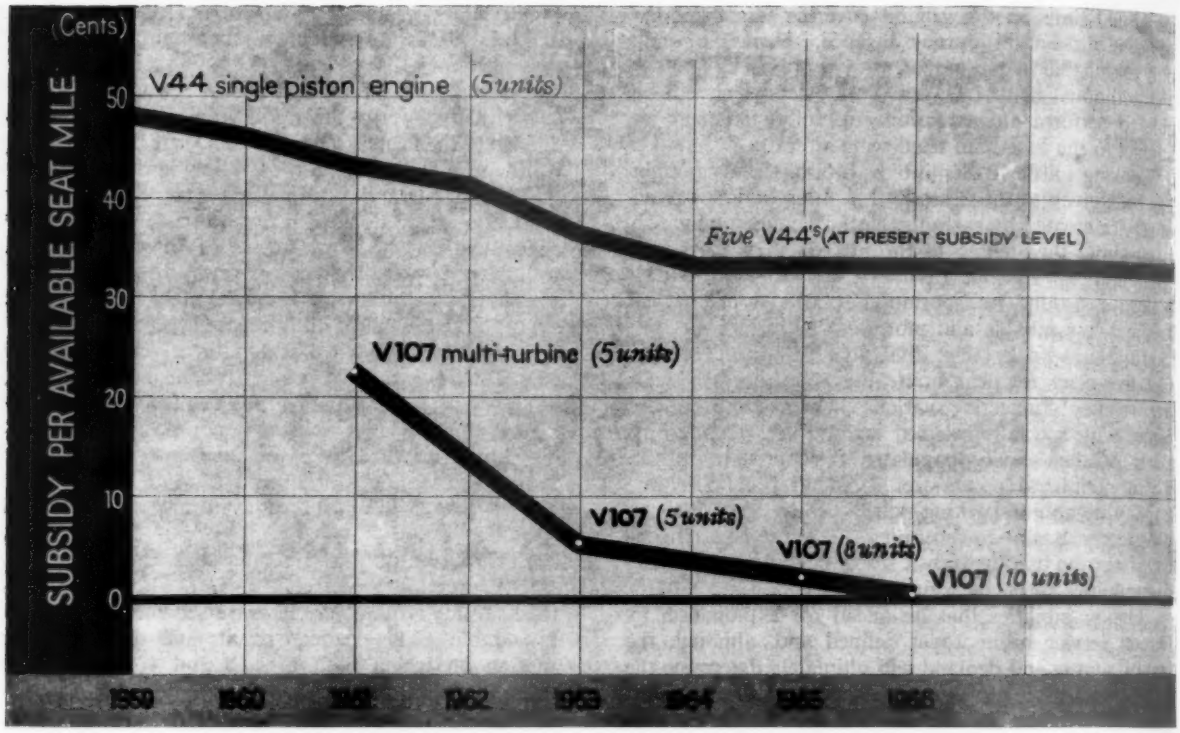

FIGURE 3. Transition from operations with five V 44s to ten V 107s. Relation between fleet potential and subsidy per available seat mile.

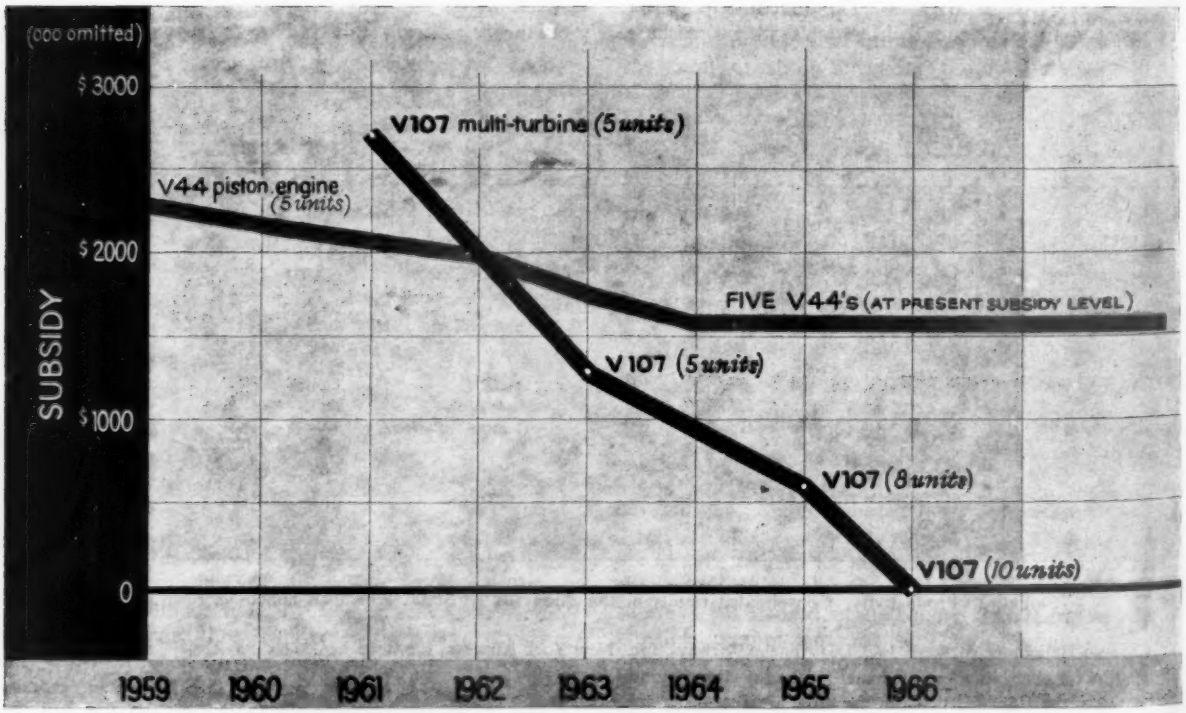

FIGURE 4. Transition from operations with five V 44s to ten V 107s. Relation between fleet potential and subsidy.

FIGURE 5. Passengers boarding New York Airways' new Boeing-Vertol 107 helicoper.

made to expand greatly the scheduling of service to suburban communities and neighbouring cities.

The determination to purchase the new multi-turbine equipment was reached only after the comfort of our passengers, as well as purely economic factors, had received careful attention. We studied the cabin noise and vibration levels and found that, in these regards, this aircraft not only represents an improvement over our present helicopters but also has an advantage over many fixed wing aircraft now in use.

Furthermore, numerous measurements show that the external noise level of the Vertol 107 is lower than that of any other aircraft of comparable size. Its operation will fit easily into the ambient noise level of most suburban communities and attract a minimum of unfavourable attention.

In the preparation of our preliminary budget, the necessity for minimising "Ground Time" in a Direct Service type of operation has become increasingly apparent. As the value, size, and performance of the aircraft grows, the monetary value of small fractions of time becomes notably accentuated. Therefore, we are determined that when the new turbine fleet goes into operation, more effective and faster means for loading and unloading our aircraft will have been worked out. It is an accepted maxim in the transportation business that greater speed at a given capacity and utilisation usually means greater productivity and the consequent ability to improve earnings.

In the case of helicopter operations, in which the stage lengths are short, ground speed is almost as important as air speed. Fig. 7 demonstrates the significance of ground handling efficiency. This bar chart results from a specific study of New York Airways' proposed schedule and route structure with five Vertol 107s. It assumes that each helicopter will be away from the hangar a fixed total of six and a half hours a day on an annual basis. It shows that, by reducing the average transit time per stop on the company's routes from four minutes to three minutes (a reduction of only one minute), the number of seat miles produced per year could be increased by some 2,040,000. Since experience shows that 60 per cent of these additional seat miles would be occupied by paying passengers, our annual revenues would be increased by $442,000, with no more than a nominal increase in operating costs.

Finally, the decision to introduce multi-turbine helicopters on our routes as promptly as possible was made with full awareness that our ability to take advantage of their apparent business potential depends to a large extent on the development of an air traffic control system designed specifically to handle low altitude, high-frequency scheduled operations. It will not be possible to satisfy passengers who fly New York Airways in order to save 35 or 40 minutes with anything short of precise and frequent scheduling. Nor is it generally accepted management practice to have personnel on the payroll who are only able to work productively about 80 per cent of the time.

Because of the combination of weather conditions and operating limits imposed through the use of single-engine equipment, New York Airways has, over the years, cancelled approximately 20 per cent of its schedules (this is about twice the cancellations for the same cause, suffered by either of the other two United States operators). With multi-turbine helicopters, the door will be opened to an approach to complete elimination of this costly handicap and to the conduct of operations in all-weather conditions.

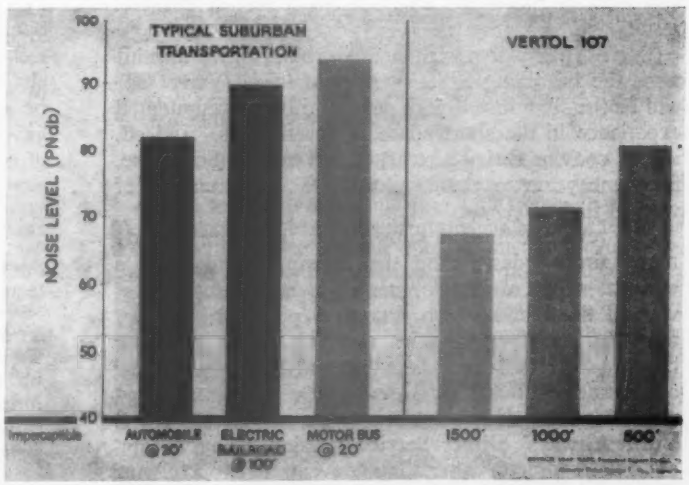

FIGURE 6. A comparison of suburban community noise level and the Vertol 107. (From U.S.A.F. W.A.D.C. Technical Report 52-204. 1952.)

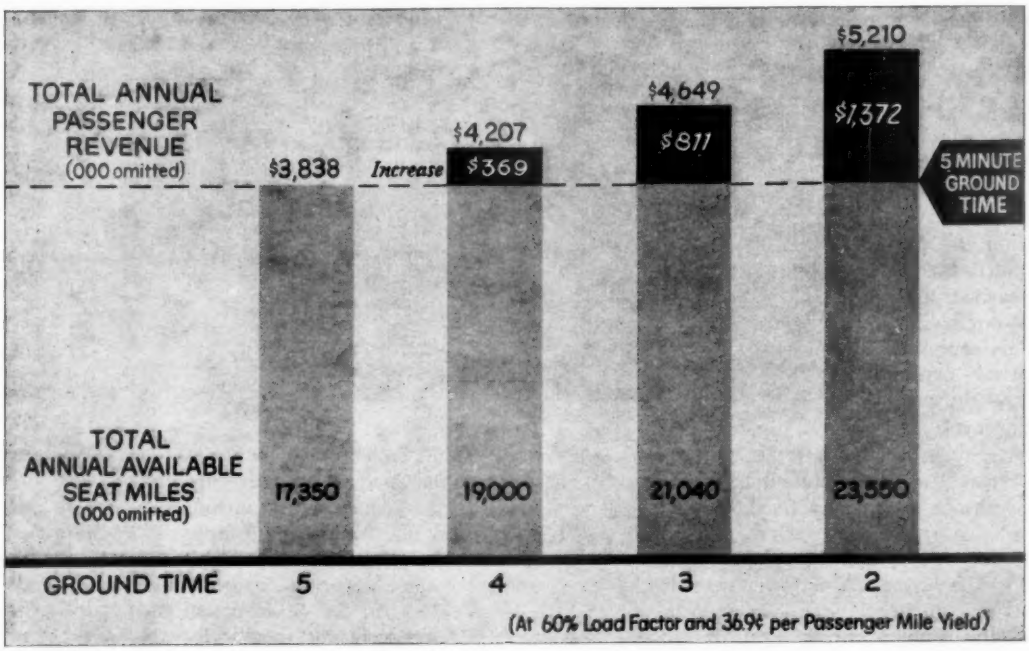

FIGURE 7. Revenue plotted against ground time. Five V107 fleet.

The Federal Aviation Agency, in recognition of the basic importance of this matter, is already implementing a "live experimentation programme" in the vicinity of New York. The stated objective of this programme is the solution of the numerous navigation and air traffic control problems involved in scheduling helicopter operations under instrument conditions in very high density traffic areas.

In conclusion, you will recall that when the commercial operation of helicopters first became a practical possibility, it was necessary to publicise and promote their extraordinary qualities. For many years we heard eloquent speeches and read colourful articles about the characteristics of rotary wing aircraft. Military uses and spectacular flights have made headlines. While doubtless this served a useful purpose, it is now clear that the time has arrived when increasing emphasis can and must be placed on obtaining hard-headed business results.

New York Airways has used rotary wing aircraft since the beginning of its operations. The Vertol 107 will be the sixth model with which we have accumulated experience in the short space of seven years. Indeed, we are convinced that aircraft of this type will continue, for some years to come, to meet the requirement for vertical flight.

However, it is well known that there are already many aircraft designs on the drawing boards and in various stages of development which are capable of vertical flight and which do not depend upon rotary wings for their performance. Since it is true that pure helicopters have the inherent disadvantage of being comparatively slow, it is reasonable to assume that sooner or later elementary economics will result in New York Airways' Direct Service mission being accomplished by aircraft other than conventional rotary wing and therefore capable of higher speeds as well as vertical flight.

Last year, with this thought in mind, we entered into an agreement with the Fairey Aviation Company which covers New York Airways' right to purchase a fleet of Rotodyne air liners. We look forward to putting these aircraft into service sometime in 1965.

Whereas it is self-evident that on long flights speed is a fundamental requirement, it is equally apparent that without vertical flight, the Direct Service type of mission cannot be satisfactorily accomplished. This is not to say either that speed is unimportant to the Direct Service operator, nor that vertical flight should be ignored by the long haul operators.

The challenge that confronts a company like New York Airways will only be answered when the highest speed economically feasible has been combined with the over-riding and basic requirement for vertical flight. Similarly, as was stated at the outset of this paper, it is well within the realm of possibility to believe that the challenge that confronts the long haul operator will not be entirely answered until the engineers and designers have joined the ability to fly vertically to the attainment of ever higher speeds.

APPENDIX

The following projection of financial results and statistical information supplements Figs. 3 and 4 of this paper and demonstrate the fleet potential in connection with New York Airways' transition from operations with five Vertol 44s (single piston-engine) to ten Vertol 107s (multi-turbine). This projection is not intended as a definitive forecast, but rather as an indication of a potential that could be achieved if certain assumptions are realised. The projections for the year 1961 contemplate the substitution of five Vertol 107s for five Vertol 44s on 30th June 1961.

RELATION BETWEEN FLEET POTENTIAL AND SUBSIDY

	1961	1963	1965	1966
	5 V44s/5 V107s	5 V107s	8 V107s	10 V107s
Commercial Revenues	$	$	$	$
Passengers Freight and Express United States Mail	1,678,000	5,967,000	9,649,000	12,073,000
Operating Expenses				
Flying Operations	855,000	1,236,000	1,927,000	2,374,000
Maintenance	955,000	1,383,000	2,174,000	2,666,000
General Services and Administration	1,463,000	2,997,000	3,821,000	4,185,000
Depreciation and Amortisation	598,000	656,000	971,000	1,201,000
Total Operating Expense	3,871,000	6,272,000	8,893,000	10,426,000
Resultant Subsidy Required to Break-Even	2,193,000	305,000	(756,000)	(1,647,000)
Return and Taxes	469,000	906,000	1,269,000	1,530,000
Resultant Total Subsidy Requirement	2,662,000	1,211,000	513,000	None
Statistics and Assumptions				
Scheduled Hours per Aircraft per Day	5:00	6:00	6:00	6:00
Performance Factor	83%	95%	95%	95%
Total Flight Hours	7,862	10,800	17,300	21,600
Revenue Miles Flown	622,000	1,100,000	1,764,000	2,205,000
Available Seat Miles	12,098,500	26,250,000	42,725,000	53,625,000
Passenger Load Factor	35%	60%	60%	60%
Revenue Passenger Miles	4,234,500	15,750,000	25,635,000	32,175,000
Revenue Passengers	235,000	875,000	1,424,000	1,788,000
Yield per Passenger Mile	36·9c	36·9c	36·9c	36·9c
Block Speed — V44B (m.p.h.)	57			
V107 (m.p.h.)	106	106	106	106
Seats per Aircraft — V44B	13			
V107	25	25	25	25

DISCUSSION

Captain J. A. Cameron (Head of Helicopter Experimental Unit, B.E.A.): What was the passenger safety record up to the present time on New York scheduled services? Secondly, could Mr. Cummings say what transmission lives could be expected on the Vertol 107 in 1961?

It was pleasing that reference had been made to Decca equipment in New York. B.E.A. had given New York Airways their first flight with Decca about seven or eight years ago; a weight penalty of 200 lb. had been allowed for dual Decca to equip their Vertol 107's. B.E.A. were now fitting a lightweight Decca, Mark VIII, weighing 70 lb., which represented quite a weight saving.

The author had referred to the fitting of the third engine to the S.61 or Vertol 107. Apart from making the aircraft more costly to operate, the third engine had the effect of reducing the vertical climb performance on these machines, with all engines operating, to the region of 100 ft. per minute, whereas the twin-engined versions were capable of 600-700 ft. per minute. This was due, of course, to transmission limitations, but since his visit to the United States a month ago one manufacturer had decided to " beef " up the transmission. This undoubtedly would improve matters.

Operationally, he was not sure at this stage just how important vertical climb was, but as the paper was on " Vertical Transport Business " one would have thought that good vertical performance was essential. Had New York Airways given thought to using the Napier "Gazelle" engine on their new Vertol 107's?

Mr. Cummings: There had been passenger safety problems. Nearly 300,000 passengers had been carried and the company had been operating since 15th October 1952.

He would ask Mr. Gallagher to comment more fully but basically the reason for the third engine was attributable directly to the fact that the company's principal problem, economically and operationally, was that 23 per cent of the schedules on a year-round basis had had to be cancelled because of weather. With two engines, this would change considerably, but with two engines (generating no more than 1,050 shaft horsepower each) on days when the temperature was on the high side it would be necessary to off-load a considerable amount of payload.

Mr. Gallagher (Vice-President, New York Airways): The New York Company had been operating the Vertol

44 helicopter, the tandem rotor helicopter, since June 1958, in schedule, and during that time they had operated over three million scheduled passenger miles. Over 170,000 passengers had been carried and over 12,000 hours flown.

During that time, there had been fourteen incidents involving the dynamic system components. There had been six engine fan problems. This was a matter of losing a blade on the cooling fan or a crack developing in the hub itself. On two occasions, this had resulted in a forced landing. The engine fan of course would not exist in the turbine engine installation.

There had been three rotor hub bearing problems and three transmission bearing problems. In no case did the incident result in having to discontinue flight. The difficulties were uncovered either by finding magnetic particles on the sump plug during routine inspections of the transmission case or, in other instances, by the pilot noticing a change in noise characteristics in the machine. The bearings were subsequently replaced during a routine maintenance period.

Two out of fourteen incidents were somewhat more serious. They were problems of a developmental nature and were concerned with rotor blades. One problem developed when the tuning weight strap parted in a forward rotor blade. The reason for the tuning strap failure was that during the course of fabrication, holes had been punched through the stainless steel strap in order to insert rivets through it. The accepted procedure, which was not followed in this instance, was to drill holes in the strap and to polish out any burrs.

The other incident developed with a failure of a spar. This, again, was caught during a routine daily inspection. Again, it was a fabrication process involving a bending of the spar, which originated from a round piece of tubing. Both of these problems were developmental in nature. They had now been resolved satisfactorily. All in all, there was not believed to be any serious problem to worry about in the transmission system or dynamic components.

The 200 lb. weight allowance in the Vertol 107 was for two complete Decca Mark VIII installations. The Mark VIII in the Vertol 44 now weighed 96-97 lb., including the bracketry, wiring, and so on. One looked forward with delight to the weight going down to 75 lb. per system, as Captain Cameron indicated. The Mark VIII system had been employed for over eighteen months, and there seemed to be good reliability in both the " black boxes " and in the signal from the ground stations. This system was the only one that could be bought at this time " off-shelf " and would give down to ground navigation reference, which was needed for the particular type of operation.

Concerning the rate of climb in the two-engined version as opposed to the three-engined version, the qualification should be added that the earlier studies of the two versus three-turbine installation were concerned with a gearbox taken from the aircraft as it now stood, a gearbox with a maximum shaft h.p. rating of 1,700. The manufacturer had now designed and begun production of, an improved gearbox which would permit a shaft h.p. rating of 2,300. In this case, one could expect much more out of the three-turbine combination than was possible from the limiting transmissions. It was further anticipated that the 2,300 shaft h.p. gearbox design would grow to 2,500 s.h.p.

In the case of twin-engined helicopters now being purchased, there was an I.F.R. requirement in the United States of an *en-route* climb of 150 ft. per minute. This meant that if an engine was lost while out on a mission, the machine must have the ability to continue flight with a minimum of 150 ft. per minute rate of climb. This could only be achieved at present up to approx. 70 deg. at full gross weight with a lightweight power plant. By including a third engine in the configuration and experiencing a one-engine-out condition, there was no problem up to a little over 100 deg. With a 1,500 s.h.p. engine installation permitting higher contingency engine ratings and, assuming the development of no other problems, it was quite possible that a twin-engine configuration might prove satisfactory from an operational as well as economic standpoint. For this reason they were currently investigating a Gazelle installation quite seriously.

The New York area suffered from somewhat higher temperatures than London and the Americans would like to have as an optimum at least a one in eight climb-out in the case of an engine failure. That made the three-engined version look quite interesting.

G. W. Stallibrass (Ministry of Aviation, *Assoc. Fellow*): It was common knowledge that efforts were being made to estimate what the future helicopter traffic might be in London and what kind of heliports might be required. It would be interesting to see what bearing Mr. Cummings' experience and forecasting might have on these points.

The paper showed an increase of 800 per cent in the traffic carried between 1959 and 1963, whereas the present load factor was only 50 per cent. What was the reason for expecting this rate of increase in passenger traffic in four years? The background to this question was that the amount of future traffic that might be expected to be carried in London would have a bearing on the number and size of heliports.

The paper gave interesting figures on average fares and also on the existing average subsidy per seat mile. Was the zero subsidy figure on the assumption that by then the helicopter would be paying the full cost of its operation, or that it would still be using heliports in cities at a nominal charge?

His third question concerned the possibility of passengers being able to get on and off helicopters in the same way as people used a bus, without booking in advance. To make this possible would surely entail a fair margin of capacity over the expected demand. Such a service was given on buses and trains in this country by cramming in passengers, in great discomfort, in the rush hours and running at a low payload factor in the off-peak hours. As in America, the railways in Britain did not pay their way. It would appear that to run that kind of service with helicopters might be expensive.

The Ministry's measurements of the Vertol 107, sketchy as they were, showed it to be very good indeed noise-wise, but the diagram shown by the author overlooked one important reaction factor. Figure 6 showed how the helicopter made less noise than an electric railway 100 ft. away or a motor car at a distance of 20 ft. The trouble with the helicopter was that it would bring noise to areas which formerly had been far more than 100 ft. from any electric railway line and often more than 20 ft. from a busy road. Had the author made any enquiries as to the sort of noise levels at which people would justifiably begin to complain?

What was the author's personal assessment of the kind of improvements that were required for helicopters to meet the communication needs which had been outlined? Two kinds of improvements had been mentioned—turbine power and the ability to maintain flight safely with one engine out. What other requirements did he consider necessary, and in what order of priority?

Mr. Cummings: On the growth of potential business, his company operated its schedules between the airports in the very high density area in question on the basis of a 50-minute frequency. However, New York Airways, due to weather problems, had had a performance factor whereby they had disappointed two of every ten people who had made a reservation on their machines. Nevertheless, 125,000 passengers had been carried in the past year. They were operating around the clock, seven days a week.

It was almost axiomatic that with an increase in frequency which was confidently expected, to approximately every 25 minutes, there would be tremendous growth in the

number of passengers. Even now, to speak of a 50 per cent load factor was not really an accurate description of what was being done. With the passenger business, this figure was exceeded. This 50 per cent included the night mail runs and other freight routes that were operated.

In its optimistic view of the future the company had not relied only upon its own judgment. The Port of New York Authority was certain that the company was understating the potential for this type of service. The New York Regional Plan Association was of the same mind. This was for the entire New York metropolitan area.

Furthermore, it could be said that if the company were not reasonably accurate in its forecasts, their approach to the Vertical Transport business would have to be modified. The fact was that New York Airways with its present plans could not make both ends of its budget meet unless it did approximate those numbers.

The company paid a nominal sum for the heliports they used. The Thirtieth Street heliport (Fig. 1), cost the Port of New York Authority 500,000 dollars capital investment. In addition, the Port of New York Authority paid the City a very substantial rental. New York Airways paid 500 dollars a month or one dollar per landing, whichever was greater, plus 600 dollars a month for a small traffic-handling building. There was, however, a sliding scale, the result of which would be that as the company's ability to pay increased, the rentals would go up.

To say that a project of this sort could pay for itself at the outset was out of the question. However the company was obviously morally obligated to do its very best to pay its way as soon as possible. If communities believed in the service, and wanted it, they just went along and helped project it into the future. At the moment matters were developing very much in the right direction, and yet the company could not possibly exist today without support from all available sources including public investors and various public agencies that were concerned.

Possibly the bus-type operations that were presently contemplated might only be operated at peak hours. The overhead costs involved in handling passengers by helicopter were roughly the same as those facing any fixed-wing operator. The difference was that, for New York Airways, the burden had to be spread over a very short stage length, with an average passenger haul of 18 miles, whereas the average passenger haul on an airline such as B.E.A. was more likely to be nearer 400 or even 500 miles. Despite this difference, however, it was necessary to have the same type of personnel and the same amount of paper work. The expensive problem thus posed must be solved in some way and the bus-type operation was only one thought on this subject.

New York Airways was much interested in creating the least possible community disturbance. Therefore, their aircraft were not likely to land in exclusively residential areas. Hence the company looked forward to operating in centrally located areas, primarily in business and suburban communities where, in any case, the maximum business would be generated.

The Vertol 107 was the quietest aircraft of its type and size that they knew of. However, even with this aircraft, there were certain areas where operations could not be conducted, simply because of the fear factor that was aroused in people when they heard something in the air over their heads. On the other hand, people were getting more accustomed to the noise of the big jet aircraft.

In reply to the question concerning assessment of the other improvements that were required it was obvious that, from the viewpoint of passenger comfort, minimum noise and vibration were essential ingredients. The internal as well as external noise levels should be better than was expected in fixed-wing aircraft. There must be quick facility for loading and unloading the aircraft, and quick fuelling facilities. The landing area should be immediately adjacent to a walk-in-area for passengers. At the moment, New York Airways was suffering from a great handicap due to the lack of adequate landing and passenger handling facilities at two of the three airports in New York; at these two airports the company was compelled to run a bus service around the airport simply to pick up passengers and baggage. This was extremely expensive, costing 150,000 - 200,000 dollars a year. For example, at La Guardia Field passengers had to be taken almost half a mile around buildings and across a taxi-way out to where the helicopter landed. At Chicago and Los Angeles, passengers were able to walk on to the aircraft. He did not know what the ultimate solution at Idlewild would be, but at present it was necessary to run a bus around that airport too (roughly two miles in circumference), to the designated helicopter landing area. It seemed reasonable to expect that sometime within the next few years special helicopter schedules would be assigned to meet special long haul fixed-wing flights, and this might minimise the difficulty. Today it constituted one of the major problems.

Air traffic control and approach aids were other essentials and constituted most important current problems confronting them. That was why New York Airways took such an active interest in the Decca Navigator System.

R. Hafner (Chief Designer (Helicopters) Bristol Aircraft Ltd., *Fellow*): A number of questions arose from recent discussions in this country, now that the problem of the short haul transport aircraft had come to the fore again. Some of them were typically domestic problems, concerning both design and operation of short haul aircraft. The questions he wished to put to the lecturer were therefore United Kingdom questions, to which he hoped useful American answers could be given.

It was interesting to have the lecturer's statement on the reduction of overheads by the discontinuation of the system of seat reservations, which was, of course, possible with aircraft operating from city centres, provided that there was a high frequency service.

He felt strongly on this point. This was one of the most effective means of reducing the cost of short haul transportation; there was an opportunity now to throw overboard a cumbersome and irritating custom of the fixed-wing aircraft. They could hope to make the helicopter popular only if they provided a frequent and simple service free from all complications.

Another important factor concerning fleet utilisation and economics was that scheduled short haul services were subject to a 24 hour cycle, with peak demand at 8.10 a.m. and 6.10 p.m. The capacity of the fleet would thus be made to meet such peak demand (allowing for a modest degree of passenger unloading) which would permit the withdrawal of some aircraft for maintenance and so on during slack periods. Goods and mail could be carried during the night. All this promised—subject to fares being right—the possibility of high load factors combined with high fleet utilisation. Did the lecturer agree?

Everybody liked to know what fares the public could reasonably be expected to pay. Obviously, the demand was flexible. If the charges were heavy, there would be only few passengers. If, on the other hand, too little was charged, there would be insufficient return for the service rendered. It was necessary to find the economic optimum. Would it be fair to assume that for ultra-short flights, such as those in the New York area, something like a taxi fare should be charged? In this case, of course, there would be no price differential between ground and air transportation and the only advantage of the helicopter would be its greater speed. Or did the lecturer feel that this was not sufficient and there should be a price differential as well, so that one would achieve an economic volume of traffic? Or, indeed, could they even charge *more* than the taxi and get away with it?

The same question could be asked in relation to intercity traffic. The lecturer had mentioned New York-Philadelphia and New York-Washington. Obviously, for such flights

the taxi rate would be rather high. Over long distances, it would probably be necessary to charge lower rates. What was the lecturer's datum for such typical inter-city journeys? Would he charge first-class air fares, and hope for a strong demand because of the convenience of the direct service, or would he consider charging even less in order to achieve the demand necessary for a high frequency service?

His next question, which related to the economics of the equipment, was directed more to Mr. Gallagher. From his 12 years' experience on design and development of multi-engined helicopters, he had developed certain definite ideas. For regular passenger transportation, he thought that multi-engined equipment, which could be flown safely in any weather, at any time without regard to ground conditions, was a *sine qua non*. There must be a clearly defined performance with an engine inoperative. There were two cases to be considered. If an engine failed *en route*, the aircraft must be capable of a modest rate of climb. This should be achieved with an engine rating which could be called the *en route* contingency rating. The aircraft would be designed to meet this requirement. In the event of an engine failure during take-off or landing much more power was needed. This was typical of all helicopters. It could be argued that the helicopter should be supplied with sufficient power to give also, with one engine inoperative, a vertical climb performance for take-off and landing. This, however, would mean rather large engines with poor economy of operation.

He had shown in various papers and many discussions that a vertical performance with one engine out was not necessary, and safe landings and take-offs could be made even in confined areas provided a certain technique was applied. This was called the backward or upward take-off technique whereby in the event of an engine failure below a certain height, the aircraft would sink back to the take-off point and, if above that height, would continue the flight by assuming forward speed. Such technique offered economic operation.

Even so, one needed for the engine failure at take-off a higher rating than the *en route* rating. This could be called the maximum contingency rating. The power demand for this contingency was very high indeed.

These ideas had been developed over the years and in 1958 a British delegation formally presented these concepts to the American Authorities and the Industry at meetings in Washington. The discussions he thought went extremely well and there was a general feeling after the meetings that good agreement had beeen reached and that all that remained to be done were matters of detail.

In the following year another Anglo-American meeting took place, and there were many who did not attend because they regarded the outcome a *fait accompli*. He was, however, surprised when he heard that views had changed and that the 2½-minute rating had been discarded.

He was completely at a loss to understand how New York Airways could operate safely with helicopters designed under the new rules. Possibly, when operating from a long runway at Idlewild or some other airport there would be no take-off problem; there was plenty of room ahead for emergency landing in the event of a terminal engine failure and, without the maximum contingency rating, it was still possible somehow to operate safely. But what happened when an engine failed at take-off in a confined space such as the landing platform at 30th Street?

One could not speak of external noise in general terms. First, there was the noise caused *en route, i.e.* when flying at a certain height over certain areas. A distinction must be drawn between flying over areas that were typically business areas—*i.e.* Manhattan, where there was much noise anyhow all day and night—and flying over dormitory areas, such as the suburbs of New York where people slept and played. What was the reaction of the population there? There one had to consider whether the service was to be during daylight hours only or a night service also. Presumably, New York Airways would be running a 24-hour service on most of their routes.

The next point concerned the noise in the actual take-off and landing area. These were specific areas which should be treated separately from those *en route*. Obviously, the noise in those areas would be greater because the aircraft was nearer the ground, also more power was used. These areas, which probably held only factories and the like, would be more conditioned to noise. Was there any problem in such areas? Were landing sites much limited in New York on account of noise?

Having thought a great deal about this problem of noise, his own view—at least, insofar as it concerned London and the United Kingdom—was that the best solution to deal with the terminal noise would be to consider railway stations as sites for heliports. With the modernisation of the British railway system, new stations would be of modern design.

They might be somewhat like New York's Grand Central station, with railway platforms underground in one or two levels. Above that, because of the great need for parking facilities, there would probably be one or two levels for car parks, and above them there could very well be the heliport platform. The areas in which the stations were sited had been conditioned to noise for a long time and would be ideal locations for heliports.

Quite apart from that, the railway stations were natural centres for transportation, where Underground, rail-, road- and air-ways could meet. One could effect through booking, say from Watford to a place near Paris, with the terminal legs of the journey made by train and the middle part by air. Had there been any thinking along those lines in the U.S.A.?

In view of New York Airways' experience with a great deal of equipment what were the reasons for their choice of the Vertol 107? There was, of course, genuine alternative equipment, using even the same engine. If the choice had been influenced by technical or economic factors, they would be interested to know. Were they primarily concerned with vibration, or with freedom from noise, or with speed, or the economics of operation?

Mr. Cummings: Generally speaking they seemed to agree with Mr. Hafner on fares. For some time it had seemed to the New York Company that there was what might be called a service factor. In other words, when operating over a densely populated area or over water or other barriers to surface transport, where there was no other means of transportation or the other means occupied an undue amount of time, it was possible to charge a higher fare than when the helicopter route paralleled a public expressway.

When flying a route such as that from La Guardia across Manhattan to Newark, the service factor was very high, because the other means of transport, not only during rush hours but at most times except on Sundays, took as much as an hour or an hour and a half. By helicopter, with the existing machines, the journey took about 17 minutes day in and day out.

In such a case, the service factor ratio would approximate four to one—the relationship of one hour to 17 minutes—and therefore it was possible to charge 56 cents per seat mile. Right now frequency appeared to be the principal limit on the number of passengers carried. So far there had been no questions whatever about the fares charged. The 71 cent fare referred to in the text was charged from Thirtieth Street, in the centre of Manhattan on the Hudson River, to Newark. Here again, there were major convenience considerations and the service factor ratio was about five to one.

When going farther out of the city into the suburbs and beyond from La Guardia field to Stamford or Bridgport, a journey of about 55 miles, the current fare was approximately 22 cents a seat mile, because this was what the traffic service factor would bear.

New York Airways did not believe that the Vertol 107 would extend on a self-sustaining economic basis for much more than 20 or 30 miles in the New York area. Again the actual distance would depend upon exactly what kind of service factor was offered.

With larger machines, such as the Fairey Rotodyne, running on schedules to, say, Philadelphia, it would be possible to charge a fare of about 12 dollars and do well on a 50 per cent load factor. This compared with a rail fare of about 7 dollars. In summary, fares were obviously going to require further consideration, but so far no problems had been caused by the present structure. Their generation of traffic had not yet reached the point where demand had been affected in that way, so far as they were aware, by the fares they charged. Certainly, reductions in fares would be projected as the efficiency of the aircraft and public need for their services developed.

He had already made some comments on heliport locations and agreed with what had been said about where they should be located. The railway station idea was right, although there had been no success yet in this direction in the United States. In Manhattan, the port area was available and in fact the company was already using one pierhead, which, as mentioned, had been made available though collaboration of the City and the Port of New York Authority. Furthermore, another pierhead would be in use next spring in the Wall Street area. On the other hand New York Airways had always thought that the Grand Central Station, in the heart of Manhattan, would be excellent as soon as there was the requisite performance in the engine and aircraft.

Concerning the choice of the Vertol 107, the matter had been studied carefully. As must be realised, New York Airways had considered as meticulously as anybody knew how, the technical and economic characteristics of all the available aircraft. The decision was not an easy one. The final choice was based upon the company's routes and requirements and nobody could possibly say how right the decision had been until after the aircraft selected had been operating for at least a year or two. The first year was not difficult with any machine. It was in the second and third years that they would know whether their expectations were justified.

Mr. Gallagher: On the question concerning the economics of the one-engine-out operation and the engine ratings, his company, as an operator, concurred with Mr. Hafner about the need for special contingency ratings.

The backward take-off manoeuvre proposed by Mr. Hafner many years ago had now been demonstrated to be an operation that could easily be executed by the average airline pilot. New York Airways had already conducted extensive experiments with vertical auto-rotations with a tandem rotor helicopter. Under full gross weight on very hot days, it was found that no extraordinary pilot skill was required. This had been found to be a definite advantage, and it had been used fully in all N.Y.A. operations.

It was important also to consider the one-engine-out condition and related handling characteristics, particularly with regard to the rearward take-off technique. Good stability and control must be achieved without the sacrifice of other required handling characteristics. The end result should be to provide the pilot, when flying manually, with the inherent stability needed for routine instrument flight throughout the entire speed range.

Particularly from the passenger acceptance standpoint the lowest possible noise and vibration levels must be achieved. They had found that any vibrating couple emanating from resultant vibrations and acting in a vertical plane had a decidedly negative effect on passenger comfort because the motion was parallel to the spinal column. The achievement of an acceptable level of passenger comfort was indeed an important consideration. The location of noisy and heavy components, such as transmissions and engines, away from the passenger cabin contributed substantially to the well-being and comfort of the passenger. The fuel tanks mounted externally ahead of the main landing gear support structure reduced significantly the potential hazards of fuel fire. Certain other design safety features of interest were the use of oil lubricated hubs, improved drive system, dual hydraulic control, excellent cockpit visibility, water landing capability to Sea State 3 conditions, and a simplified longitudinal control system. The elimination of cyclic control had reduced the number of control components by 25 per cent.

In the final analysis the considerations enumerated produced economic results which permitted an earnings forecast attractive enough to make the use of helicopters a self-supporting business enterprise some time under given conditions in the not too distant future. It was self-evident that day-to-day operating efficiency was of controlling importance in producing the desired economic results. The basic detail design philosophy and objectives of the V-107 had been directed specifically to the requirements of the commercial operator. Dynamic system components had been designed to achieve an unlimited service life and in certain areas outlast the useful life of the aircraft. A high degree of accessibility permitting thorough inspection of the vital components and the performance of preventative maintenance operations had been designed into the basic aircraft.

Dr. G. S. Hislop (Chief Engineer, Fairey Aviation Ltd., *Fellow*): Was the author's definition of "completion factor" identical with what was sometimes called "performance factor."

Mr. Cummings: Yes, it was.

Dr. Hislop: He noticed that the author was only allowing an improvement from 80 to 85 per cent in completion factor with the advent of what he called the turbine engine, which, presumably, was really the advent of twin engines—namely the Vertol 107. Was this a reflection of the fact that Mr. Cummings did not expect, with two engines, that the single-engine performance would be adequate. Hence a third engine might be necessary and that this in turn would show what one expected would be a quite spectacular improvement in performance factor? With good single-engine performance, it would then be possible to operate under fairly low weather limits, given the right aids in the New York area.

He had himself experienced the annoying business of having to take the bus to the helicopter at La Guardia and Idlewild. Was this due to an un-co-operative attitude of the airport authority in making the company park its helicopters well away from the apron, as distinct from the attitude that was apparent in Chicago, where the operator was allowed to come very close?

There was, however, a difference in technique at Chicago. Although there was apparently quite a lot of ground taxying there and the authorities were prepared to allow taxying from the apron or from the gate to the take-off point, N.Y.A. appeared to take-off from a point where the passengers embarked. Was this a difference forced on the operator, or a difference of choice?

One would regard as somewhat questionable the economics of on-demand seating, with people arriving unexpectedly and getting in and having tickets issued. This type of traffic was of a character which varied immensely in volume during the day. With a fleet which was capable of dealing with most of the demand at 100 per cent load factor during the day at the peak hour, and assuming aircraft were withdrawn from service (as one speaker had suggested) until the average load factor during off-peak hours fell to, say, 70 per cent, one would have thought that the average utilisation throughout the year would drop very low indeed—down to, say, under 1,000 hours, which would be unattractive. This might be amenable to

fairly exact estimate, given a knowledge of the fluctuation in potential traffic on an hourly basis. It then might not look quite so good as would appear when thinking about it loosely.

The expectations of rate of traffic growth in the New York area were interesting. It would be interesting also to compare the company's expectations for 1960 with the predictions made by the Port of New York Authority when producing its magnificent document showing the growth between 1955 and 1965. How had the actual traffic compared with those predictions?

Mr. Cummings: The projection of 83 per cent completion factor for the calendar year 1961 on one of the charts was based on the fact that the first half of the year would be operated with the present Vertol 44 fleet with single piston engines. The chart showing 85 per cent for the calendar year 1962 was based on a V.F.R. operation with a fleet of five turbine-powered Vertol 107's. Furthermore, it would not be possible to forecast operations under all-weather conditions until appropriate air traffic control procedures had been developed along with the necessary instrumentation.

Concerning the attitude of the Port Authority and New York Airways present inability to operate into specific gate positions, the company was, of course, upset, especially since at Brussels, Chicago and Los Angeles it was possible to operate right into the gates and passengers could walk on board the helicopters without any bus transportation being required. However, in the interests of the air transportation industry as a whole, it must be understood that there were reasons resulting from fixed-wing congestion which did not permit the Port Authority to do much better at this time for the company. Nevertheless, a great deal of pressure was maintained upon the Authority, because running buses was extremely costly and the public service the company was able to offer suffered badly.

More specifically, the present situation arose from the fact that La Guardia was designed and built before anybody had any vision at all about the present traffic requirements. Now, however, La Guardia was undergoing a substantial modification programme, as a result of which it should be possible to achieve a much better arrangement for everyone, including helicopters. Even so, it would be two years before the modifications were completed. Nevertheless, the conclusion had been reached that it was necessary for New York Airways to be more tolerant at La Guardia than at other places. New York International also was in a period of transition, but it was hoped that even as early as this coming summer they would be able to operate into at least one specific gate position, thus substantially improving present arrangements.

R. A. Shaw (Ministry of Aviation, *Fellow*): He could not let the occasion pass without complimenting somebody in America—presumably, the Fathers of New York City—on having such enterprise and vision that they would subsidise such an organisation as New York Airways to do this operational exercise.

It seemed inevitable that pure vertical take-off aircraft would be noiser than helicopters. They were likely to be available in about the same time scale as some of the helicopters that were now being considered. What did Mr. Cummings consider to be necessary in the way of landing arrangements for them? He had not mentioned the possibility of using tall buildings, but one would have thought that in the United States, particularly in the New York area, somebody must have contemplated the possibility of using the roofs of very tall buildings to enable these aircraft to land and take off without causing a great deal of noise to the population as a whole.

Even with helicopters, there might be some advantage in meeting the engine-cut case if the operator knew that he had a good free fall once he was airborne!

Mr. Cummings: His company would not be in business but for the fact that they believed that it would not be too long before they would be free of the necessity of going hat-in-hand to Washington to obtain government funds. While this requirement continued, however, it was most reassuring to have the support that was currently given and the demonstration of the belief in New York Airways' future that existed in various Government agencies. There was no question whatever about this.

That was why it should be emphasised that one's concern was not merely with the day-to-day operation, but rather in the future. It was generally agreed that the potential of New York Airways was large. The company had invested a great deal of money, time and energy in it with the full support of the Government and other people, including New York Airways' stockholders, numbering some 800, who had never had a dividend. Today the company was worth about 2½ million dollars.

Thought had been given to the use of tall buildings as landing places, but the company had been considerably inhibited in its projections in this direction for reasons already mentioned and also, because as soon as mention was made of the possibility of landing on tall buildings, inevitably somebody thought it could be done now with single-engine equipment. With the advent of the additional source of power, the situation would change and the company would doubtless develop new techniques and new ideas that could be pursued more actively than had seemed advisable thus far.

As a matter of fact the company had been negotiating for six months for a landing site on the roof of a new tall building in the downtown area. There was, however, the problem that the building in question had a big air conditioning plant on the roof which would have to be shut off when an aircraft was landing because it created an unusually high degree of turbulence. Turbulent updraft conditions resulting from the wind hitting the sides of the building also needed careful consideration, but investigations were proceeding with a scale model to discover exactly what the practical possibilities might be.

Professor J. A. J. Bennett (the Chairman): He was interested particularly in what Mr. Gallagher had said about one of the factors affecting the choice of tandem rotors in preference to a single main rotor, *i.e.* that there had been no trouble in the vortex ring state. Possibly this was due to the fact that the differential pitch component of control remained effective independently of the overall lift. The resulting differential lift could maintain the desired attitude of the fuselage even when cyclic pitch control became ineffective.

It would seem, however, that this feature could be simulated in the single rotor arrangement by the use of offset flapping hinges because cyclic pitch control would then be adequate for control of attitude independent of the overall lift. Even if the collective lift were substantially zero, there would still be longitudinal control in the tandem rotor helicopter from the difierential lift of the two rotors, and similarly in the single rotor helicopter with offset flapping hinges there would also be control because the effect of cyclic pitch change would be to transmit differential lift to the offset hinges. Thus the Westminster and Rotodyne would be expected to be free from vortex ring state trouble.

He was sure that members would wish to congratulate the author not only for his lecture, but also for having already established a successful "vertical transport business" in New York City. He thanked Mr. Cummings and also Mr. Gallagher for coming over from the United States.

The Development and Flight Testing of Helicopters

by

G. J. SARSTED,* B.Sc., and A. V. COLES†, B.Sc.

(*Head of Technical Development Department, †Senior Flight Development Engineer, Helicopter Division, Bristol Aircraft Ltd.)

The final meeting of the Helicopter Association of Great Britain was held on 8th January 1960 at 4 Hamilton Place, London, W.1, when a lecture "The Development and Flight Testing of Helicopters" was given by Mr. G. J. Sarsted, B.Sc. and Mr. A. V. Coles, B.Sc., of Bristol Aircraft Ltd. Professor J. A. J. Bennett, Chairman of the Association, presided.

Opening the Meeting Professor Bennett announced on behalf of the Executive Council of the Helicoper Association that the arrangements which were being made with the Royal Aeronautical Society for a merger had now matured as a result of the Extraordinary General Meeting held that afternoon.

This meeting was, therefore, the final one of the Helicopter Association of Great Britain. Many would regard it as an occasion for looking back over the past fourteen years since the Association was formed with a sense of no mean achievement. Now, however, opportunities that lay ahead were the main concern and, with the extension of the Association's activities to a larger membership, the future indeed held a considerable challenge. There should be no appreciable discontinuity at this juncture, because the meetings would continue to be held, as usual, on the first Friday evening of each month at the same time and the same place.

The first part of the paper that evening would be presented by Mr. G. J. Sarsted, Head of the Technical Development Department of the Bristol Aircraft Company's Helicopter Division at Weston-super-Mare. Mr. Sarsted had held this position since 1956, having previously served in the Royal Air Force and worked in the Engineering Development Laboratory of Bristol Aircraft Ltd. for five years on ground and flight testing of fixed wing aircraft as well as helicopters.

The second part of the paper would be presented by Mr. A. V. Coles, who joined the Bristol Company as a student apprentice in 1945 and, since taking his degree in aeronautical engineering at the University of Bristol in 1953, had been working on helicopter flight testing at Bristol Aircraft Ltd. He was now Senior Flight Development Engineer (Helicopters).

SUMMARY: The successful development of a helicopter and its introduction into service may be influenced by several factors but a well co-ordinated development programme is by far the most important. A practical and realistic balance between representative ground tests and the subsequent flight proving is essential if the project is to be completed within a reasonable budget and time scale. The two parts of this paper cover these phases and aim to show how they are related in a particular development programme. The use of major fully representative ground rigs is discussed in relation to pre-flight functioning and fatigue life assessment; this is followed by the initial flight trials and finally the structural and performance clearance of the helicopter over its full design envelope. Although the tests and techniques described are generally applicable, the examples quoted relate to the Bristol Type 192, tandem rotor helicopter. The opinions expressed are personal and do not necessarily represent those of the Bristol Aircraft Limited.

PART 1

by G. J. SARSTED

1. Introduction

There have been considerable advances in both design and application of the helicopter over the past ten years. It has firmly established itself by proving not only its versatility but more its particular usefulness in certain applications. The helicopter has proved itself in spite of active competition from light fixed-wing aircraft and land and water-borne transport.

The operator has readily appreciated the value of the helicopter and his demands have helped to create active competition in the industry.

This has been a great stimulus to engineers in the helicopter business but has also led to a very complicated machine.

The ever changing demand for greater range, better load carrying capacity, all-weather operating ability, has not only led to complex engineering problems, but produced difficult specifications and extensive test programmes for development and final clearance.

Although the helicopter problems associated with controls, transmission and vibration remain fundamentally the same for designs of similar configuration, the engineering problems become more complicated as design advances and it is essential that development, testing techniques and instrumentation keep pace with the machine.

While helicopter development has followed a fairly regular pattern over the past few years and the engineer has had "fixed-wing techniques" or "experience of the previous type" to call upon when formulating his test programme, development has now reached a stage with the advent of turbine engines, power-operated controls and automatic pilots where the engineer has little past experience to call upon.

The requirements, test programmes and instrumentation must be related to the helicopter if the development and final clearance phases are to be achieved at reasonable cost and allow introduction of the machine into service with a reasonably useful life span.

This paper deals with the ground and flight development phases of helicopters produced by Bristol Aircraft

Ltd., in particular the Type 192, tandem rotor helicopter. It would not be possible to cover in detail all the tests necessary to clear a helicopter into service and the routine engineering tests associated with product development such as material control, casting and forging strength tests, system functioning and so on are dealt with very briefly. Where test requirements have necessitated a particular form of development or where techniques used are considered advanced, or entirely new, the whole test phase is covered in some detail.

The paper covers the testing stage from early "hardware", and component test rigs to structural and flight clearance of the prototype.

2. Initial Component Tests

This section covers the work of a routine nature and the components referred to are tested on machines that are normally standard equipment in mechanical and fatigue laboratories, supplemented by minor special purpose rigs.

(*a*) Material control tests; evaluation of processes; special material selection.

(*b*) Strength tests of control levers, shafts, minor structural components, followed by fatigue tests on fabricated components, shaft and control couplings, etc.

(*c*) Strength tests of major castings and forgings.

(*d*) Main Rotor Hub. The basic testing of this unit followed the normal pattern of a strength and deflection investigation, load being applied hydraulically through the flapping hinge pins. This was supplemented with strain lacquer tests which gave indications of the stress concentrations and served as a guide for the location of strain gauges, used in the later phases of hub development on the rotor tower, transmission test rig and finally the prototype helicopter. Photoelastic models were used for investigating hub lug stresses.

The use of fully strain-gauged aircraft type hubs on the rotor tower and transmission rig proved a valuable aid to life assessment and formed the basis for the initial overhaul periods.

(*e*) Transmission components. A number of photoelastic models were made for the investigation of gear tooth stresses, but the main strength and fatigue tests were conducted on the complete transmission system installed in the transmission rig (Fig. 1). The freewheel unit however presented a different problem and it was considered that a rig to clear the unit for strength, functioning and fatigue would be both elaborate and expensive.

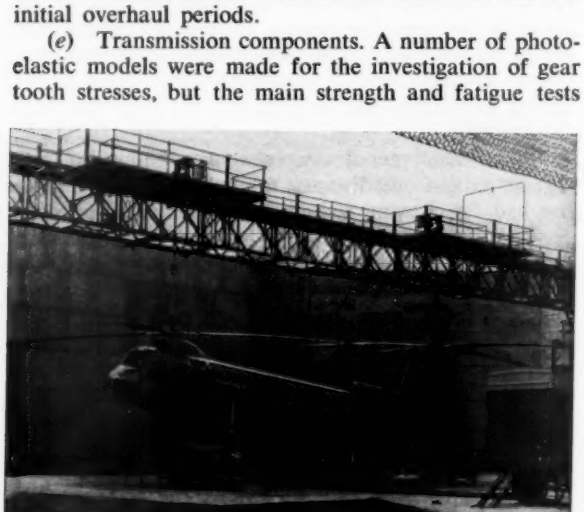

FIGURE 1. Transmission test rig.

As the freewheel was of the dog-clutch type the development was conducted in three phases. Photoelastic models were used for stress analysis and as a guide to suitable tooth form. Clutch members formed on dummy shafts were then strength tested on a standard torsion machine and several specimens were later fatigue tested.

The second stage was functioning, engagement and endurance testing with the unit in the complete gearbox, mounted on the freewheel test rig (Fig. 5).

The final stage was normal and overload running when installed with the complete helicopter engine rotor transmission system mounted in the transmission rig (Fig. 1).

3. Major Tests

3.1. FUSELAGE STRENGTH TEST

This followed the standard principle for deflection and ultimate tests for a major structure. A completely representative fuselage was suspended, from the rotor heads, in a gantry structure. Load was applied at selected points on the fuselage through a system of beams and hydraulic jacks.

Extensive resistance strain-gauge stations provided load and stress information at selected points such as gearbox and engine attachments, bulkheads, door frames, window cut-outs and so on. A very large number of the strain-gauge groups were attached during sub-assembly stages of the fuselage and although accidental damage during final assembly did occur, the technique proved valuable both in time saved and the greater amount of information gained.

3.2. FUEL SYSTEM

Although the finalising of this system could only be achieved by flight testing, the use of a rig provided valuable information that enabled a fully developed system to be installed in the aircraft. The rig itself was a functional layout of tanks, pipe system, flow meters and so on mounted on an adjustable structure which enabled attitudes of roll and pitch to be simulated.

The testing provided information on flow rates, tank venting, fuel jettison, tank/structure attachments, etc.

3.3. GROUND RESONANCE

This has always been a major problem of clearance and particularly in the case of a helicopter.

A considerable amount of time has been spent on research, and extensive model and full-scale aircraft tests have been done, particularly on the Type 173 tandem rotor helicopter. This work has been fully reported by Howarth and Jones[1] and Hooper[2].

In the case of the Bristol Type 192, ground resonance checks were made on the prototype during early ground running. The aircraft excitation was provided by varying degrees and rates of "stick-stir", the

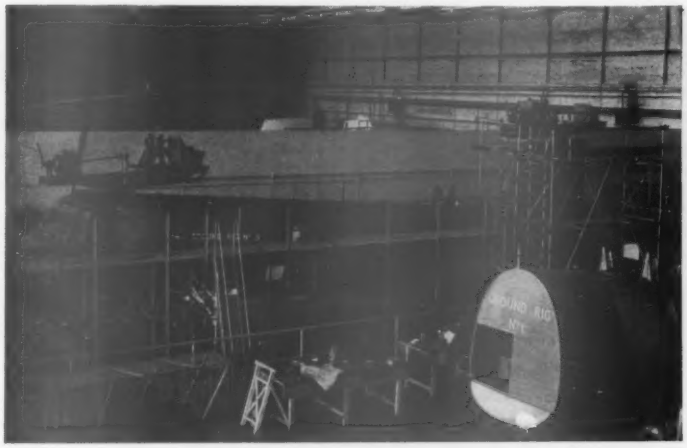

FIGURE 2. Controls test rig.

response being measured by electrical-type acceleration transducers mounted at several points in the fuselage, at the rotor heads and on the undercarriages.

4. Major Rig Tests

As the design and development of helicopters have advanced it has become increasingly important to have more pre-flight knowledge of the many systems together with fatigue lives of the critical items.

Towards this end the use of full-scale ground rigs, as nearly representative of the actual helicopter as possible, has proved to be invaluable.

In the case of the Bristol Type 192, three complete airframes were used purely as test rigs; one for the development and testing of the flying control systems, the other two for development and proving of the complete engine/rotor transmission systems.

The instrumentation on the rigs was identical to that on the prototype aircraft and the early information obtained from the rigs greatly reduced the number of last minute modifications on the prototype.

The early flights were started with pre-knowledge of the major systems such as controls and transmission together with a fair idea of fatigue lives within the initial flight envelope.

The flight observers were faced with the same instrumentation and prior knowledge of many of the "trouble spots" with the result that the initial "probing flights" were relatively straightforward and a general assessment of the helicopter was completed fairly quickly. The early flight results were fed back into the rig programmes and extensive running maintained "safe life, fatigue and stress information" well ahead of the actual flight programme. This technique has certainly helped all concerned to tackle the more intensive flight trials with a much greater degree of confidence.

4.1. FLYING CONTROLS TEST RIG (Fig. 2)

In the past the ultimate strength requirements for control systems have been met by deflection and destruction tests on individual components supplemented by fatigue tests on items and in some cases subassemblies.

The functioning of the complete system and its dynamic response could only be determined by actual flight testing of the prototype. This method brought to light many shortcomings in the method of testing and modifications to the aircraft caused many delays to the flight programme. Furthermore, fatigue life had to be based on calculation and substantiated as flight experience was gained.

It was considered that a ground rig, with a fully representative aircraft control system, provided with a suitable form of excitation could provide the best solution. The rig could be used in the initial stages to develop the control geometry and later to clear system functioning, endurance running, response and resonance checks, and ultimately fatigue life. By this means a fully tested control system with a known life could be built into the helicopter.

The development and fatigue clearance of the manual flying control system for the Bristol Type 192 was achieved by the use of such a rig.

Theory and practical experience on the Type 173 tandem rotor helicopter had shown that loads in flight were induced by aerodynamic and mechanical excitation from the rotors; also that the loads most likely to cause fatigue failure occurred at a frequency of once per blade (approx. 16 c./sec.). Detailed analysis of flight records indicated that the loads came within two categories. Those occurring during steady level flight and referred to later as "cruise" and much heavier transient loads during violent manoeuvres referred to as "flare-out". Furthermore, the rotor excitation could be defined by two components, "collective" and "cyclic" and any desired degree of coupling achieved by suitable phasing of the excitation.

The rig (Fig. 2) consisted of a complete Type 191 airframe, modified to be fully representative of the Type 192 structure, mounted on an undercarriage acting as a low frequency support. A complete and fully instrumented Type 192 control system was installed. Control loads were sensed by strain gauges, while displacements and angular positions were measured by electrical potentiometer pick-ups. The outputs from these various transducers were fed to suitable amplifiers and thence to a photographic recorder. Selected channels of information were also displayed on an oscilloscope type recorder for monitoring purposes.

Identical exciter systems were mounted at each rotor head providing collective and cyclic excitation. The need for accurate speed control and phasing led to the choice of synchronous motors for the drive.

4.2. COLLECTIVE EXCITER (Fig. 3)

This was of the displacement type, the movement of a variable throw eccentric being transmitted via beam springs and a yoke to the collective pitch cone.

The beam springs were designed to represent

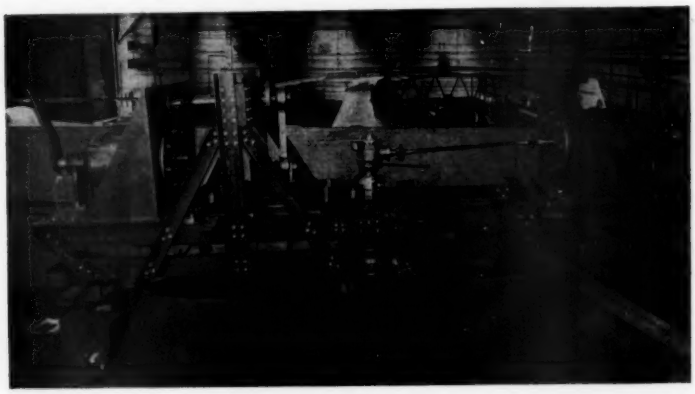

FIGURE 3. Collective cyclic exciter system.

propeller moment and tie-bar torque, normally balanced in the collective system by the collective pitch bias springs.

4.3. CYCLIC EXCITER (Fig. 3)

This was essentially a Lanchester gear type of exciter. The bevel gearbox was attached to the control axle in the position normally occupied by the control spider. Out of balance masses were attached to the arms mounted on the bevel wheels. The drive to the input pinion was through a shaft and flexible couplings having a high torsional stiffness but low axial and angular stiffnesses; this allowed the cyclic control system complete freedom of movement over its whole range. By varying the coincidence point of the two arms a rotating load vector of varying magnitude could be produced at the bottom of the control axle approximating to the cyclic excitation in flight.

The supporting structures for the exciters were deliberately made robust and designed to have natural frequencies well removed from that of the excitation. These structures were attached to the rotor axles in the positions normally occupied by the rotor gearboxes. The phase relationship of the driving motors could be altered by mechanically rotating the motor body in its mounting cradle. To ensure that the four machines ran at exactly the same speed they were fed from a common supply and to allow for a range of speeds to be covered this supply was of variable frequency. Contacts fitted to the four exciters and connected to the starter controls through a suitable triggering circuit ensured that the four motors locked into synchronism in their correct relative phase positions.

4.4. TEST PROGRAMME

The main purpose of the rig was to prove the functioning of the control system and provide some fatigue clearance before the prototype flew. Therefore, initial rig running was based on estimated loads. From flight test records for the Type 173, the most severe loads occurring in each control for any flight condition were extracted; these were factored for increased all-up weight and scatter, a further factor being applied to allow indefinite life clearance in some 110 hours of testing.

The study of typical flight patterns and previous test records showed that "flare-out" loads occurred for about 10 per cent of the time. Therefore, it was decided to cycle the test in the same fashion; running for 10 per cent of the total time at "flare-out" level and the remainder at "cruise".

When early flight test results were available the rig programme was modified to suit but in general the clearance obtained, based on estimated loads, held good.

This type of rig has proved itself a valuable development tool in many ways; it has not only provided a sound method of fatigue clearance but has brought to light undesirable engineering and assembly features which could not have been highlighted by testing individual components.

Possibly the main disadvantage with a rig of this type is that a failure or modification completely stopped testing until a replacement was available.

However, for a rig as complex as this to realise its full value, a comprehensive spares backing must be readily available and the testing should be sufficiently ahead of the aircraft to offset the unavoidable stoppages.

4.5. TRANSMISSION TEST RIGS

The policy adopted for the development and clearance of the engine/rotor transmission system was also based on the same philosophy. Two complete, Type 191, airframes were modified to take Napier Gazelle free turbine engines and completely representative, Type 192, transmission, gearbox and rotor systems. These major rigs were supplemented by three special purpose rigs for detailed investigations on particular items.

4.6. FREEWHEEL TEST RIG (Fig. 5)

Freewheel devices of the "dog-clutch" type are incorporated in the aircraft gearboxes on the input drive shafts. These units are subjected to all types of loading and infallable operation is of the utmost importance. During normal twin-engine operation both units are driving but in the event of an engine failure the adjacent freewheel starts "ratchetting". Furthermore, engine

FIGURE 4. Strain-gauged layshaft pinion.

FIGURE 5. Freewheel test rig.

surging could cause intermittent engagement and disengagement and the case of engine restarting in flight, resulting in snatch engagements must also be considered.

The rig was designed to simulate all these conditions utilising the whole freewheel unit in its normal environment. As mentioned earlier, ultimate strength and fatigue tests were done separately and it now remained to clear the unit for functioning, lubrication, endurance and wear.

Basically the rig consisted of an aircraft gearbox with variable speed motors driving the input and synchronising shafts. Lubrication was provided by a separate system with temperature and flow control. Dynamic characteristics of the transmission system were simulated by suitable flywheels.

The relative speeds and azimuth positions of the upper and lower freewheel members were recorded using potentiometer and inductive pick-ups.

Strain gauge groups measuring torsion in the lower member were used to indicate the point of engagement and the fluctuating stress levels; the depth of tooth engagement was recorded by inductive probes.

4.7. GEARBOX LUBRICATION RIG (Fig. 6)

Many of the troubles found in gearboxes are often the result of faulty lubrication and the value of thorough development of this system is soon appreciated when serious ground running and flight tests commence.

The rig was designed to be fully representative of the aircraft system in all essential details. Gearboxes, oil coolers, oil tanks and pipe runs were mounted in their correct relative positions; long pipe runs were simulated in length but coiled for convenience. The driving effort was provided by a variable speed motor and suitable transducers provided indications of pressures, temperatures, flow rates, froth content and so on. Manually-operated valves in the system enabled line blockage and pump failure to be simulated.

Initially the rig was used for jet calibration and development; for this phase gears and gearbox covers were removed and the pump remained the only driven unit. Jet sizes and positions were adjusted until the best flow pattern and distribution were obtained. Elapsed time from the starting of the pumps to the establishment of effective flow from the jets was checked for a range of oil temperatures.

The next stage was running of the fully assembled system and to keep power requirements to a minimum the gears were assembled without bearing end-nips. This phase was a lengthy one and covered gearbox drainage and venting, functioning of oil coolers and filters, pump performance, operation of relief valves, the effect of simulated failures and system functioning over a range of temperatures. Also, as modifications were introduced tests had to be repeated.

4.8. GEARBOX DEFLECTION TEST (Fig. 4)

When a gearbox is subjected to load, the distortion of the casing and shafts causes malalignment of the gears, resulting in bad load distribution along the teeth; any degree of localised tooth loading leads to reduction of static strength and fatigue life. Futhermore, it is not possible to have gears meshing correctly for all power conditions.

It was generally agreed that a deliberate malalignment of the gears in the unloaded state could be tolerated, provided uniform tooth load distribution and correct alignment were achieved when transmitting full power. Having established the required offsets by deflection tests the aircraft gearboxes were built with the appropriate degree of malalignment.

Early methods using lead plugs between the meshing teeth were both laborious and unreliable; the gearbox having to be stripped and plugs replaced after each loading cycle. A most successful solution was provided by the development of the strain-gauge technique described.

Load distribution along a gear tooth was measured by strain gauges attached to the non-driving face, equally spaced and with the gauge elements running

FIGURE 6. Gear box lubrication rig.

from tip to root; foil pads slightly thicker than the gauges protected them from damage in the case of accidental rotation in the wrong direction.

The gear malalignments were varied by using a series of special bearings with eccentrically ground outer tracks.

Before assembly the strain-gauged gears were calibrated in a standard compression testing machine. Loads were applied to the working face of the tooth through a short parallel roller; each section of tooth being loaded separately with the centre lines of roller and strain-gauge coincident.

Incremental loading was applied and signals from the "loaded gauge" and the adjacent ones were recorded; from these calibrations influence coefficient curves were plotted for each strain-gauge position.

The assembled gearbox was then mounted in the rig and subjected to a series of torque loadings corresponding to the aircraft powers; the gears being rotated through a full meshing cycle at each load condition. The above cycle was repeated until satisfactory gear meshing and load distribution were attained.

4.9. TRANSMISSION TEST RIG (Fig. 1)

The final development, endurance running, overload and fatigue testing of the transmission and rotor systems is accomplished on the two turbine-powered rigs already referred to.

The instrumentation on both rigs is very comprehensive and, in addition to all the normal engine, gearbox and rotor quantities, information on transient loads is provided by strain gauges, pressure transducers, accelerometers and so on, and presented on oscilloscope or photographic recorders in the control caravan.

Engine power is absorbed by drogues attached to the rotor blades and by varying the sizes any combination of engine or gearbox powers can be achieved. To obtain representative vertical loads in the gearbox thrust bearings, the rigs are suspended by low frequency supports from a gantry structure.

Apart from the clearance of the transmission system at present flying in the Bristol Type 192, the rigs have provided valuable development experience on engine control and starting systems, simulated engine and transmission failures, rotor hubs and new gear designs.

4.10. STRUCTURAL FLIGHT TESTING

Although all the ground testing may have been programmed and controlled to be as realistic as possible it can never completely simulate flight conditions. The prototype machine will always be the "ultimate" in test rigs.

A major contribution towards the success of and the rate at which this structural clearance can be achieved is provided by extensive and reliable test instrumentation.

In the case of the Type 192, strain gauges provide the means for measuring steady and fluctuating stresses in the rotor blades, hubs, gearboxes, transmission system, engine and gearbox mounting structures, control systems, tailplane and airframe. For other measurements, pressure, temperature, vibration, various commercial and self-manufactured transducers are used.

The heart of the system is a multi-channel amplifying unit coupled to a 50 channel photographic recorder. The outputs from all the "pick-ups" are fed to a "programming panel" situated adjacent to the recording equipment, enabling any desired groups of information to be selected in flight.

PART 2—FLIGHT TESTING

by A. V. COLES

1. Introduction

The flight test phase in the development of any aircraft may seem to be the most dramatic of all work leading to a successful machine. However, to be done effectively, flight testing must have been considered from the inception of the project and throughout the manufacturing and engineering development phases.

The experience on which this paper has been based is that of Bristol single and tandem rotor helicopters. The author believes that any helicopter must suffer similar birth pangs before emerging as a satisfactory flight tested machine.

2. Planning of Flight Test Work

When a new helicopter is projected it is not enough to suggest that when an airframe is completed, and sufficient engineering development satisfactorily behind, someone shall be asked to fly it to see if it works! From the beginning of any new project test aircraft must become available in a logical order so that flight tests can proceed economically and profitably.

The precise planning of a new helicopter will, of course, depend on the scale of the venture. In the case of a small P.V. only one or perhaps two aircraft may be flown initially until sales interest has been aroused. In the case of a large manufacturing contract it is possible that five or six development aircraft may be available in fairly quick succession to speed development work.

However many aircraft are available for development, the flight test programme must ensure that the maximum amount of information is obtained as quickly as possible. It is essential however, that this thirst for knowledge at an early stage in development does not get out of hand and lead to a programme of tests in one field which is not adequately backed up in other directions. During the early stages of flight testing it is most probable that considerable development is taking place in other fields leading to a rapidly varying standard for initial aircraft. One must ensure that in this fluid period the right test is being performed on the right aircraft, or one may find that much flight test time has been wasted and must, in part at least, be repeated at a more representative standard of build.

The initial flight tests of a typical flight test programme of a new helicopter are usually devoted to hovering, and limited forward flight, tests to establish initial data on those aspects of the aircraft which cannot be fully covered by ground development tests. These include:—

(*a*) Flying controls; aerodynamic response, pilot's control forces and control loads to substantiate component lives estimated from ground development tests.

(*b*) Rotor blades; aerodynamic behaviour, *e.g.* tracking and balancing in flight, flutter, power requirements, rotor blade and hub loads in flight.

(*c*) Transmission and/or engine; function and ease of handling in flight, cooling, throttle response, transmission loads and/or performance in flight.

(*d*) Systems effected by flight environment; *e.g.* electrical generator cooling, power control system cooling and cycling, ventilation.

When initial flight tests have established the general safety of operation of the helicopter over a very limited flight envelope, it is then necessary to extend such tests to cover the full design flight envelope of air speed, rotor speed, altitude, all-up weight and centre of gravity range. At this stage it is possible to separate the types of test into a series of development aircraft, if these are available. A typical division might be to specialise one aircraft, probably the first, on those tests measuring structural loads to establish system safety and ultimately settle fatigue lives for production aircraft. Simultaneously a second aircraft can conveniently specialise in tests to establish performance and handling data for the type. These two aircraft must inevitably carry considerable instrumentation. If available, a third aircraft with a minimum of instrumentation should embark on those role and operational tests which demand full operational payload, the role equipment being fitted as required.

As experience is gained on the type it may be appropriate to use the second aircraft for Type Tests, and the third aircraft for customer trials, retaining the first aircraft for further company development.

3. Problems in Flight Tests

In the early stages of flight tests a great deal of guidance is expected from the various design departments. This will often be related to the flight envelope variables, such as air speed, altitude and rotor r.p.m. over ranges of weight and centre of gravity positions. It is most important that flight test data should be related to these prophesies as closely as possible, and this is not always as simple as might be supposed.

The loading of the structure of a helicopter and its controls and systems is also subject to the wide range of flight variables and it is a major problem to provide instrumentation to record the behaviour of the aircraft without running up an astronomic number of recording channels. It is usual to make a strategic choice from all the aircraft systems and monitor these instrument signals throughout the initial flight testing over an expanding flight envelope. To simplify the task of the flight test crew it has been our practice to display all the quantities monitored so that a standard deflection represents the maximum tolerable signal in a particular channel of recording.

In this way an observer can monitor a large number of channels and warn of impending large signals in order that flight tests may be limited to avoid overshooting present maximum loads. The pilot may have warning advice from up to 100 channels of recorded information to guide his early flying so as to minimise risks to the aircraft.

When a reasonable amount of experience has been acquired over a particular flight envelope the flight tests may be repeated to gain the detailed information required on each system. As the flight tests continue information also accumulates on the performance and handling of the aircraft. This preliminary data is of great assistance in planning specific performance and stability tests which have the appropriate slant for the aircraft's peculiarities.

To illustrate the problems which may arise during the development flight tests I propose to discuss some of the problems personally experienced and the way in which they have been tackled, if not solved.

A fundamental problem in any new helicopter on development flights is that of establishing an accurate and consistent presentation of air speed for the pilot and instrumentation as early as possible. The production Pitot and static positions will be decided after prolonged testing but cannot be relied upon initially to function without embarrassing position errors.

A convenient way out of the situation is to fit a Pitot-static head in some position on the aircraft where a minimum error may be anticipated. This usually involves a probe in front of the nose of the helicopter to position the Pitot-static head at about one half the rotor blade radius. In such a position downwash effects in forward flight are reduced and since a Pitot-static head will read quite accurately for relative velocities up to 10° from the axis of the head a consistent air speed measurement may be achieved. In practice such an installation has a small but consistent position error for all aircraft attitudes, which may be compared with a typical separate Pitot-static installation as in Fig. 7. The large changes of position error of the latter with changing air flow angles over the airframe may lead a pilot into considerable air speed indicator chasing at low speed. Changing the fuselage attitude may produce an air speed indication varying more rapidly than the true air speed. The Bristol 173 for instance had a Pitot-static installation so sensitive to pitch and yaw that at one time the aircraft was thought to be unflyable below 40 knots. Since the aircraft could be flown on visual or formation references slower than this a change of Pitot-static head was instituted which made it possible to fly without formation aids down to the A.S.I. limit of 20 knots.

The installation of an instrumented probe on a development helicopter invites the use of this probe for

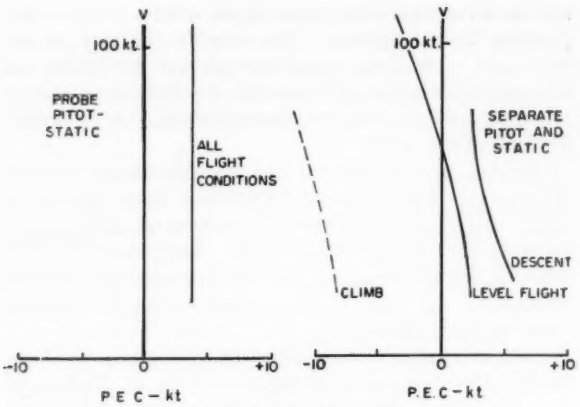

FIGURE 7. Air speed position error corrections.

other purposes. On the Bristol 192 a yaw vane mounted on such a probe showed that without the guidance of a yaw vane pilots habitually flew the aircraft with some 10° of starboard slip. This was eventually traced to the fact that, when flown without slip the aircraft was rolled to port some 2° and when a pilot kept the turn and slip indicator centralised the aircraft was slipping to starboard. A simple modification, rotating the turn and slip indicator 2° in the instrument panel resolved the situation; although the yaw vane has been retained for test purposes.

Even given the appropriate and adequate instrumentation it is not always easy to achieve accurate flight test results. Some sorts of flight test may demand interesting techniques to be developed. At one time it was thought by my organisation that we had arrived at a very convenient method of measuring the cruising flight performance of a helicopter. We had decided that it was easier for the pilot, and for the technicians analysing the test results, to measure performance in climbing or descending flight only. The pilot was briefed to fly at a particular power and rotor speed at a variety of air speeds while records were taken of the associated rate of climb or descent. The results obtained, at a series of powers, could be readily reduced to a series of graphs of rate of climb or descent against air speed, for standard weight and atmospheric conditions.

The consistency of such results was found to be very good and it was a simple matter to extract from the results at zero rate of climb a curve showing power required to fly in level flight over the speed range. The alternative test to determine level speed performance directly requires the pilot to monitor power, rotor speed, air speed and height simultaneously and has the disadvantage of requiring a more complex analytical process to reduce results to standard conditions. However, when results for level flight performance obtained by the two methods were compared it was found that the power required indicated by the climb technique was always higher than that measured directly in level flight, although the scatter of test results was noticeably less for the climb technique. No obvious explanation exists for this anomaly and indeed some climb test results which were fortuitously at zero rate of climb were indicating higher powers than comparable level flight test results taken immediately afterwards. Since records of control movements required in each case showed that a climb result was much more economic in control motion than a level, it is difficult to see where the difference in power can be dissipated. To date no satisfactory explanation of this discrepancy has come to my notice and we regrettably continue to test climb and level flight performance separately and show results which are not quite consistent. Fortunately we are in good company as results gleaned from A. & A.E.E. flight test reports on a Bristol Sycamore show a similar discrepancy[3].

Sometimes a particular helicopter has innovations which have a profound effect on flight tests. The Bristol 192 for example was one of the earliest helicopters to fly with twin free turbine power plants. These are arranged, as has been described by my ex-colleague Mr. C. H. Jones in his recent paper[4] to be interconnected so as to provide an automatic increase of power of one engine in the event of failure of the other. Unfortunately the engine torque in a free turbine engine is dependent upon transmission speed.

It was possible therefore to operate the Bristol 192 at low powers and high rotor speeds in such a way that, if the engine torques were not synchronised, one engine was operating at a torque which was low enough to be regarded by the engine safeguards as a failing drive system and it would be stopped by these safeguards to protect the engine. In such a circumstance an engine failure was experienced in flight during a high speed low power descent and we had our first demonstration that the emergency power safeguards worked. Considerable development has been directed towards achieving a reliable minimum power flight idling stop which is infallible, no matter how low a power is selected, without sacrificing engine safeguards at any time in flight.

The use of two gas turbines in Type 192, disposed as they are at each end of the fuselage, means that in flight the fuselage can be almost completely enveloped in exhaust gas streams. The jet pipes are facing substantially athwartships, at the top of vertically mounted engines, discharging at the shoulder level of the main fuselage cross section. In order to obtain data for tailplane and ventilation design the jet streams have been made visible by the introduction of smoke in both front and rear engine efflux. Figs. 8 and 9 show the exhaust efflux from one side of the front engine jet pipes. In Fig. 8, at 40 knots, it will be seen that the efflux carries well clear of the fuselage before being deflected down and aft by the rotor and free stream air flows. In Fig. 9, at 80 knots, the efflux is attached to the fuselage and sweeps diagonally downward over the flank of the fuselage. The exhaust efflux when aft of the aircraft can be seen to be separated by the vortices shed by a succession of rotor blades. In anticipation of exhaust efflux flows such as shown, positions for the ventilation intakes for the main cabin were selected as high up on the roof of the cabin as possible. Tests have shown that these intakes draw in substantially

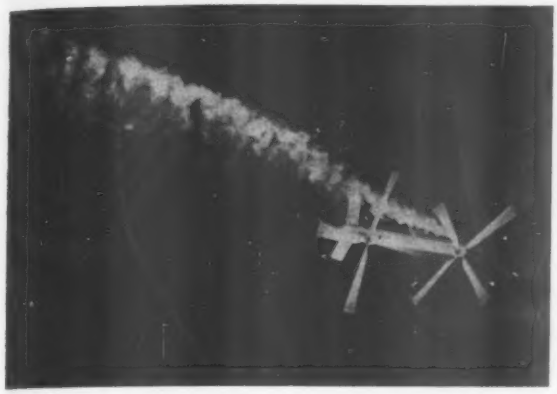

FIGURE 8. Exhaust efflux at 40 knots.

FIGURE 9. Exhaust efflux at 80 knots.

uncontaminated air in all flight conditions. It is fortunate in this respect that should exhaust efflux be drawn into the cabin, for example in hovering where recirculation in the downwash is high, the Napier Gazelles do not apparently produce measurable quantities of carbon monoxide in their exhausts. Contamination of the cabin air with exhaust in these circumstances is therefore limited to slight oily smells and an increase in air temperature above ambient.

When the exhaust efflux of the front engine is made visible it can be seen that, in cruising flight, flow from the port jet pipe flows backward and then tends to cross over the top of the fuselage in the region of the main fin. This air flow pattern, with rotation from the front rotor downwash inducing flow across the main fin, has been the cause of some difficulty with rudder control range of Bristol 192. Tandem rotor helicopters, while having a basic balance of torque between the two main rotors, have some residual rotor torque due to such factors as rotor interference effects on the rear rotor and the effects of offset centre of gravity position. In the design stages of the Bristol 192 it was calculated that these effects would not produce a large residual torque at any point in the flight envelope. In practice however, considerable starboard rudder was required as air speed increased, which was offset by rotating the end fins of the tailplane and rigging the rudder controls with a bias to starboard. When it was necessary to dispense with the end fins of the tailplane, a temporary offset split flap was added to the trailing edge of the main fin. The necessity for using starboard rudder was suspected to be due to the angle of attack of the main fin produced by downwash rotation. To produce a yawing moment of the right order the side load on the fin should be 750 lb. at 100 knots. This order of side load implies an angle of attack at the fin of some 10°. The tab applied to the fin, to be effective in reducing the side load, must be on the top surface of the fin aerofoil. In practice the wedge split flap used as an experiment was found to be relatively ineffective as there was a serious breakaway of air flow on the lifting surface of the fin aerofoil.

The angle of attack of the fin has been recorded as some 10° in cruising flight and a deflection of the whole trailing edge of the fin has been required to reduce the fin side load to a point where only a small part of the yaw control range is used in cruising flight (Fig. 10).

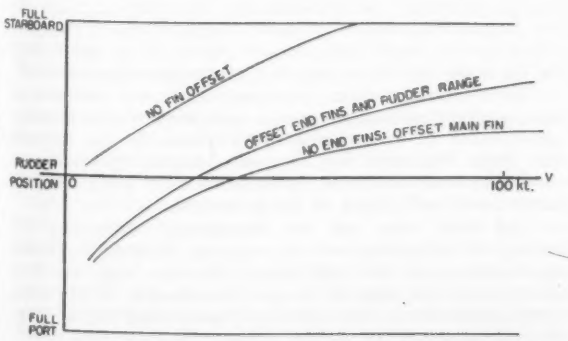

FIGURE 10. Bristol type 192 rudder position to trim.

4. Conclusions

This paper may serve to illustrate the absorbing interest and significance of the flight test phase of a helicopter. Dramatic it may be, but to be too dramatic is indicative of incomplete planning and co-ordination of this critical stage. It is better to make headlines by delivering helicopters than in any other way.

May I take this opportunity on behalf of Mr. Sarsted and myself of thanking the Bristol Aircraft Ltd. for permission to present this paper and our colleagues for the help they have given.

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DISCUSSION

T. G. G. Newbery (Ministry of Aviation, *Assoc. Fellow*): He was very interested in the philosophy which had been expressed, particularly by Mr. Sarsted, that the logical way to carry out a development programme for a helicopter was to start off with small rig testing work on individual components and details and to work up to the final testing of the complete installation in a representative environment.

There was, however, one point which seemed to be missing. On the transmission development, all the endurance testing had been done in the gantry rig, by testing of the complete system. While there was no doubt that this method of testing had definite advantages, one would have thought that there was a case for having individual gearbox rig tests, such as the back-to-back type of rig, so that the individual boxes themselves could have been tested and the worst of the bugs eliminated before the complete system was put together in the gantry rig for the testing under the correct environmental conditions. He would welcome Mr. Sarsted's comments on this.

Thinking of the question on the broader basis the main point that one would like to ask the authors was: in the light of the experience they had obtained in the testing of the Bristol 192, what changes in their planning would they make if they were now given the task of mapping out the development and test programme for a comparable new type of helicopter?

Mr. Sarsted had referred to the increasing testing requirements with new types of helicopters. During recent years, thoughts and ideas on these requirements and on the procedures had changed considerably, and changes were still to be expected. Much thought was being given to this and, obviously, it was necessary that advantage be taken of all the experience that was obtained.

There might be a case for a critical review and report on completion of the development testing of each new helicopter type. This would have the advantage that the lessons to be learned would not be lost either to the firms, or to the authorities, such as could occur as a result of changes in personnel or because of the human fallibility of short memory.

On the flying side, he agreed absolutely that the final testing must be of the complete helicopter. One possible question had already been answered by Mr. Coles' figure showing that in the case of the 192 six development aircraft were planned and also indicating the way that the work was divided between them. In planning a new programme, would Mr. Coles advocate six aircraft and would he allocate the tasks in a similar manner?

How much total flying would Mr. Coles plan in the development flight programme? One of the directions in which, one felt, experience must be gained was in adequate flight under actual operational conditions.

Mr. Sarsted: The question about why there was no back-to-back testing for the 192 was a welcome one. What happened was that the gearboxes had to be tested rather hurriedly. The decision to test them by means of a fully representative ground rig was right. As stated in the paper, the trend for the future appeared to be that in the clearance of major systems and new designs, more representative and elaborate ground rigs, suitably programmed, could indeed shorten the development phases considerably.

One had toyed with the idea of back-to-back rigs. Indeed, at one time, such a rig existed at the Bristol Company. It was easy to be wise afterwards, but there were several features of the design that had, indeed, done more harm than good to the gearboxes.

The advantage in the case of the 192 was that the rig on which the gearboxes were tested was at least representative of the aeroplane. The speeding up of testing of individual gearboxes and the sorting out of some of the troubles associated with them, *e.g.* auxiliary gearboxes, and even main drive gearboxes, could be helped considerably by the back-to-back system, but careful attention must be paid to the details of the design. It was an aid to development leading to the design of a gearbox rather than a rig for proving that a gearbox had reached a stage of finality of design.

That was why it should be stressed that the major rigs not only should be capable of dealing with the product that the company was considering at any specific moment, but should allow for the development of that design and the development of new products. There was room for both the back-to-back type of rig and also, at a later stage of the development of the gearbox, the type of rig illustrated in the paper.

Concerning changes in plans that might be decided upon in the light of experience, from the viewpoint of the test departments there was always a group of individuals who held up progress or allowed too short a time in which to get an answer. The first of the improvements that one would suggest would be to have a manufacturing organisation that produced ironmongery without paper work. It was far more important to be able to drill a hole in a component where one wanted it, than to go through all the argument and paper work about why it was necessary. Once something had been developed, people could go into elaborate paper schemes, release notes and all the rest, but there must always be a quick answer to development testing. If the designer wanted something done, if the technician knew what he wanted done, then he should have adequate machine shop backing and test facilities. That would be one essential requirement for any new product that was considered.

Secondly, the rigs should not merely be based upon those described in the paper, but taken a stage farther. When designing, say, a helicopter with a power control system and auto-stabilisers, the rig that one designed to start with should not merely prove the control system in the prototype. It should cater for the initial design, and further development of power controls. These systems, fed back to analogue computers coupled with ground rigs, could provide valuable research information and could allow development on a much broader field than one had been able to achieve in a rig which was purely representative of the product being built.

One should also make sure that the rig design was well advanced—indeed, was ahead of the aircraft design in some instances—so that there would not be all the last-minute worry of trying to get the 10, 100 or 200 hours of life assessment on a panic basis just before the prototype flew. There should be time to do that sort of work on a rig—to introduce the modifications on a logical basis, retest the machine, make sure one's assumptions were correct and then put it all into the aeroplane. This meant that the rig must be well in advance of the prototype aircraft.

These were the main requirements. It was essential to have a good engineering shop to back the test organisation, appreciation in the original specification for the aircraft that there was need for rigs and adequate provision to supply and pay for them, apart from them being comprehensive and well ahead of the prototype.

The third item was the regulations concerning the testing of helicopters and the current tendency to revise the requirements for helicopters. For too long, one had put up with the aircraft design requirements of the fixed wing aeroplane as referred to, or interpreted for, helicopters. This would not do any longer.

The sort of things that were associated with power

controls were flight flutter tests; although comparatively straightforward, it was absolutely impossible to do them as specified for rotating wing aircraft. The broad test requirements in the specifications must be more closely related to helicopters and rotary wing aircraft than they had been in the past. Certainly, there was now a tendency towards this direction, but it must be reviewed even more critically. There were certain things that could assist the initial development work and development flying of helicopters a great deal if the requirements were tailored with helicopters, rather than general aeroplanes, in mind.

Mr. Coles: He could only agree with Mr. Sarsted that in the case of a subsequent aeroplane, the main improvement that they could make in their technique was to ensure, by adequate ground testing, that when the time came to fly the aeroplane one was reasonably sure that it was the right aeroplane, both from an engineering viewpoint and from a policy standpoint. If one could be sure of this, it would be possible to make do with fewer aeroplanes and more flying would be done on aeroplanes closer to the production standard. This would be the major advance to be made on the flight test side and it would be possible if, from the onset, the aeroplane was a reasonably stabilised engineering entity.

The first aircraft available could not avoid doing the basic structural proving of the aeroplane and the basic proving of the handling. The second aeroplane would fill out this information in respect of performance and the handling of systems and would probably go on for tropical trials. The third aeroplane would be needed for consumer tests, both for the company and for the customer.

Most of the trouble which had been encountered on both the Sycamore and the 192 had come about largely from having a lot of late-stage modifications introduced on a variety of aeroplanes. One was forever juggling with a bunch of aeroplanes, trying to find the right one for the right test.

That only brought into much sharper definition the problem, of which Mr. Sarsted had spoken, of the engineering facilities that were necessary to back one's programme. The greater the number of modifications and variables, obviously the more work one must put on to the shelf.

If there were an adequately ground-tested aeroplane, it would be possible to get along with fewer prototypes and one would be glad to do a great deal more flying than it was possible to do at the moment with the varying field with which one seemed to be faced.

On the question of a critical report, which Mr. Newbery had raised, there would be a great deal to be learned, as suggested by Mr. Sarsted, in the light of the application of the rules to each particular helicopter in turn. The critical report would to some extent reveal whether the rules fitted the aeroplane, or *vice versa*.

Captain W. B. Axford, R.N. (Retd.) (Westland Aircraft Ltd., *Assoc. Fellow*): They had heard a lot about rigs and naturally, with his background he was bound to state how lucky Bristol were. He would have given a great deal to have had full-scale fuselage rigs for certain tasks that had to be done. On the other hand, it was possible to be misguided by having wholly representative rigs firmly tethered by one end or the other to the ground.

In a flight control system for a helicopter, there were loadings that were completely unpredictable at the design stage, particularly when going to a fully powered system with no manual reversion. In that connection, he completely supported the paper in stating that a full-scale rig was essential. His only question, therefore, concerning the control rig was to ask why, instead of the rather elaborate system of synchronous motors and cams, vibrator techniques were not used to excite the cyclic and the collective channels.

Concerning transmission testing, a fuselage rig could easily lead people "up the garden path". If it were possible to get the basic transmission design together with forecast vibratory loads built into a rig, the loading could be factored to a point where it was possible to accelerate the test and thus the assessment of the lives of the transmission components and gears far more quickly than could be done certainly with a fuselage rig driven by a Gazelle engine.

What factors had the authors used to establish the fatigue lives of transmission components with drag plates on the blades and two Gazelles at either end? Admittedly, a stronger shaft was probably put in between them, but it must have taken a lot of calculation to use a complete fuselage as a fatigue test rig.

Mr. Sarsted: Captain Axford had similar feelings to himself in terms of "rigs, rigs and more rigs", although there might be some variation of idea on the extent to which these should be representative.

The moving coil type of exciter had, in fact, been considered for the control rig. This, however, was a case where one had to represent the two forms of excitation—the collective excitation, which was essentially something that was vertically up and down, and cyclic excitation, which was represented by a rotating vector but had to be represented in one of several disc planes. In other words, the axle had to be free to move over its full normal control range. Moving coil exciters had to be rigidly mounted and carefully aligned. To allow for the various control attitudes this would have entailed an elaborate and heavy adjustable supporting structure. With the powers involved large and expensive drive amplifiers would also be required.

Since hub and blades had to be represented in terms of propeller movement by beam springs, the easiest means of achieving collective excitation from there was to drive it by a crank and obtain the rotating load vector with an exciter whose movement did not affect the engineering to any great extent. The whole unit could be mounted on a fairly simple stiff structure with a frequency well removed from excitation.

Both methods had been considered. If the design using moving coil exciters had been developed, the frequency control problem and the locking of the excitation in phase would have been much easier. With the system adopted (synchronous machines), it was achieved by having a common supply.

A master contactor on one machine electrically locked the other three machines in their correct phase relationships. As a means of exciting the control system in the two degrees of freedom that were wanted, the rig had provided a good solution.

The next question concerned the fatigue testing of the transmission and the extent of progress using Gazelles. To quote from the design specification of the 192, the normal twin-engine cruise condition would be 1,050 h.p. per engine. Obviously, they had worked up in stages through the power range.

The calculations were based on torque loads to the gearboxes over a typical flight pattern. With 100 hours running at appropriate torque levels a fatigue clearance of the order of 75 hours had been achieved. These figures were merely comparative; the underlying detailed argument was involved.

Using as a guide the normal cruise condition, they had worked up to the stage where, running at 1,150 h.p. twin-engine, for 60 hours had given a 200 hours fatigue life clearance of the main gear. Thirty-five hours running at 1,355-1,400 h.p. twin-engine would be required for the indefinite fatigue clearance of the transmission system in terms of the main gear alone. This running gave percentage clearances for lives of other components, *e.g.* of input pinion and layshaft.

In the case of the 192, there was a twin-engine peak performance at 1,050 h.p. and single-engined peak performance at 1,650 h.p.

By testing on the gantry rig and using it for fatigue work also, it was possible for ground running purposes to exceed these engine powers. Admittedly, structure modification was necessary for the rear fin because, being the basic airframe, it was not designed for these peak conditions. The stage now being worked up to was 1,350 h.p. and above twin-engine, and 1,650 h.p. and above single engine.

Admittedly with this sort of rig for clearing a gearbox from a fatigue point of view, failure at these high powers would result in a lot of expensive broken rig. It might be considered better to have fatigue rigs for individual gearboxes because if anything went wrong, it was easier to replace.

To offset that, experience had been gained of the life of the synchronising shaft bearings, the effect of fuselage torsion on the bearing stations, and bearing temperatures under actual running environment with the helicopter suspended. All this was valuable experience, coupled with the fact that one could work up in incremental powers obtaining clearances for various systems as one worked up through the range.

This method, supplemented with the back-to-back type of rig for initial development and, perhaps, smaller rigs to clear individual fatigue cases, was one way of tackling the problem, but running the overall system as one was helpful in evaluating several other quantities.

H. J. Webb (Airborne and Helicopter Division, A. & A.E.E., Boscombe Down, *Assoc. Fellow*): He endorsed Mr. Sarsted's statement that the instrumentation on the rigs should be the same as that on the flight aircraft. This had not always been so, and it had taken many years to get the firms to realise that this practice should be followed. What one had not yet seen, however, was the correlation between the results from the rig tests and the subsequent flight tests to demonstrate that the correct cases had indeed, been chosen for the rig tests.

Concerning rigs the authors' company had been fortunate in having one or two spare fuselages, of a similar type which were not required for flight. This answered the statement made by Captain Axford when commenting on their good fortune.

Mr. Sarsted had said at the end of his paper, however, that if he had to plan for another helicopter, he would indeed make out a case for that type of rig—in other words, the equivalent of a flying shell as opposed to lumps of concrete and rolled steel joists.

It was interesting to see the amount of work that had been done in developing the helicopter under review. The authors had filled a gap, in that the Authority specified certain requirements in S.P.970 and the Testing Establishment saw the resulting end product. Tonight, members had learned what happened in between, and as could be seen this added up to a fair amount of work.

He was interested to hear about Mr. Coles' testing and his smoke generator: he had done some of the flight testing on the aircraft himself in relation to this contamination. Presumably, the pictures which had been shown were stills from a ciné record and not merely still photographs taken under stabilised conditions: in other words, they were from a dynamic record of what was happening.

Mr. Coles: They were stills, but he had both kinds.

Mr. Webb: During the flight tests, contamination was observed during changes in flight attitude, such as during turning flight or changing from cruising to climbing, and *vice versa*. He hoped eventually to be able to see some of the results from the authors' hovering tests, a condition which might show some degree of contamination.

R. D. Trumper (Fairey Aviation Ltd.): In emphasising the need for spares backing, the authors had left a seed of doubt in his mind concerning rigs. Would the authors indicate briefly how the relative proportions of flying and ground running were distributed among the six aircraft which they had shown?

At a previous lecture, Mr. Newbery had made some rather harsh remarks about the technique of strain-gauging being a major stumbling block in the development of aircraft. In view of the extent to which the authors had used these techniques, it would be interesting to know whether they, too, had found them troublesome and what steps they had taken to overcome these difficulties.

Colin Faulkner (Saunders-Roe Ltd., *Assoc. Fellow*): The authors had been lucky with both time and money. Mr. Sarsted's paper, if he interpreted it correctly, dealt exclusively with anticipated troubles. Mr. Coles' paper now and again gave remarks which afforded clues to the existence of unanticipated troubles. It would be interesting to know a little more about these. To put it bluntly, after the extremely elegant pre-flight development programme described by the authors, what went wrong and what were the cures?

Of necessity, Saunders-Roe had always had to tackle the job a different way, and one was not so sure that they were not right in doing so. One of the first things to be established, and as quickly as possible, was whether the aircraft would fly and whether it was flyable. One's experience was that a lot of modifications could come through the system after the first two or three hours' flying and that these could well invalidate much of the previous anticipatory test work. If they at Saunders-Roe had their choice over again they would probably confine their pre-flight work to some back-to-back gearbox testing and a few other elementary things, but it was doubtful whether they would go to the same lengths as the authors' company.

One example was that of the fatigue testing of the control circuit before flying. On what did they base the input loads and frequencies? Like Captain Axford, he simply did not know these until the aircraft had been flown. One could, of course, have a fair idea when using fully manual control systems as, obviously, they could not be too bad or the pilot would not take-off. One could not help feeling that the emphasis had been, perhaps, a little too much on the preliminary ground testing and not enough on achieving an early first flight date. He too felt that there should be rigs, rigs and more rigs, but it was a question of precisely when the bulk of this testing should be phased-in to the overall programme.

Had the authors applied their strain gauge techniques to spiral bevel gears?

On the rudder pedal-to-trim curves shown, the biggest change was a datum shift in hover, and the influence of fin incidence seemed relatively small. Surely rephasing of the control circuit had been the major influence, rather than the cure discussed by Mr. Coles?

Mr. Coles: He thanked their friends in the Industry for their co-operation. In terms of what was the difference between rig testing and flight testing, both Mr. Webb and Mr. Faulkner wished to know what went wrong. Mr. Webb could be answered with two things that went right between the rig testing and the flight testing. One was that the control loads that were fed into the control rig were, to all practical intents and purposes, substantiated in flight by similar measurements on the flight aircraft. Therefore, the rig was a valid piece of test equipment.

Between the gantry and the flight aircraft, there were

several very useful cross references, a particular one being the engine failure cases, where it was possible to demonstrate the failure of an engine, the automatic increase in power of the remaining engine and the effect of all this on the aircraft as a system. From this, it was predicted that the pilot would not know what had happened. This was true and it was possible to show it in flight. The effect of engine failure in flight was a drop of 2-3 r.p.m., and that was all. It was a useful demonstration that rigs did, in fact, work.

In the reverse sense, one had sympathy with Mr. Faulkner. Despite all the rig tests, there had been considerable changes to the aeroplane as a result of the early flights. Some of the changes were for engineering reasons and some for longer-term policy reasons. To cite particular examples, since the aeroplane first flew the form of the rotor blades had been changed from wooden tapered blades to parallel metal blades and there had been a change from manual controls to a system of one channel of power and one channel of manual reversion. These things had, to some extent, come about as a result of the early test flying. One sympathised with Mr. Faulkner in saying that this was something which could not be predicted and which could always happen.

In terms of the amount of flying and ground running time that had been clocked up, the proportion at the moment stood at about between two and three to one in favour of gantry time. There had been between two and three times as much time on the complete gantry as had been accumulated in aircraft time, and this could be regarded as a happy state of affairs.

In terms of the distribution of time on the various aeroplanes, the whole six had not yet been flown, although a programme for six had been shown. Four had, in fact, been flown, and it could be said that the time flown was virtually in proportion to the order in which the aircraft became available, *i.e.* four units for the first, three for the second, and so on. This was the natural order of events as the aeroplanes became available. The stage had not yet been reached where it was possible to indulge in intensive flying. They had not finished intensively flight testing the validation of the aeroplane's safety in all respects.

Mr. Sarsted: He wished first to take up the idea that the ground testing highlighted things that were likely to happen. Even if they were not likely to happen, they certainly did happen. Pumps seized, gears failed and all sorts of things happened. The paper attempted to highlight the use of a rig in trying to resolve these issues.

The changing of the engineering detail and design and the changes that were made after functioning and endurance tests all came about as a result of failure of some form during the initial stages. These failures having been sorted out on the rig and the design having been changed in detail, reduced the amount of engineering needed on the prototype.

There were two control systems and one spare allocated to the rig for fatigue testing, the remaining six aircraft having one control system apiece. The unfortunate part was the rate at which all this came together. This emphasised again the need to have a rig well ahead of the aeroplane.

Certain changes in control levers and items came about as a result of rig testing on the controls fatigue rig. But these changes had not quite caught up with the prototype aircraft, which meant that the prototype aircraft was operating with the earlier type of control lever in it with a life of so many hours. The next machine was operating, perhaps, with a control lever of a much earlier standard and an even shorter life. Once the complete control system was tested on the rig, it was necessary to spring into action and ensure that it went into the flight aircraft also.

Pre-formed strain gauges had been developed that would make it possible to strain gauge the root or flank of any gear shape. In the development of the strain gauge, a certain amount of work had been done at Teddington and Rotol as well as at Bristol. All the gauges shown in the illustrations of the gears were specially developed for gear work with a maximum thickness of 0·003 in. and an element length of $\frac{1}{8}$ in. There were also pre-formed gauges in the roots of the teeth. This was the present state of development.

In most cases, Araldite was used as the working medium for both sticking and waterproofing the system. Use was made of Araldite filler or Araldite D as the waterproofing agent. On rotor blades, the wiring layout and the gauge stations themselves were fully pocketed and were covered with a layer of Araldite D or Araldite filler to make up the aerodynamic form of the blade. This had given very good weatherproofing and there had been over 100 hours of trouble-free life on the rotor tower running in all weathers during erosion tests. The use of these epoxy resins as a sticking-on and waterproofing medium had been very successful.

Good instrumentation was necessary, and one endorsed what was said to this effect during the earlier lecture by Mr. Newbery. Most people tended to get far behind. Instrumentation was not keeping up with the demands of engineering on aeroplanes and helicopters nowadays. The need for reliable instrumentation also was most important.

The Bristol Company had tried to keep similar instrumentation on both the rig and the aircraft, as well as an adequate spares backing for this instrumentation. A considerable amount of servicing was required, as well as good instrumentation backing in the test department. The development of airborne instrumentation was advancing, but it was not advancing far or fast enough for the multichannel recordings with which everyone was faced nowadays.

G. F. Langdon (A. & A.E.E., *Assoc. Fellow*): He was interested in Mr. Coles' comparison of the power results required to maintain height measured by partial climb and by level flight tests.

The experience of Helicopter Performance section at Boscombe supported Mr. Coles to the extent that it was not unusual to find some difference between the results obtained by the two methods. They did not, however, think that there was a systematic difference. The report quoted did indeed show differences of up to six knots in speed for a given power with an average difference of about two and a half knots, but on examination of nine further reports covering four types of helicopters they found a maximum discrepancy of about three knots with an average of about half a knot.

On the whole it had been found that level flight tests gave more repeatable results than partial climbs, probably because it was easy to prolong a run at a particular level speed to obtain perfectly stabilised conditions.

TECHNICAL NOTES

Lift-Curve Slope and Induced Drag Factors of Large Aspect Ratio Straight-Tapered Wings

by

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THE DIFFICULTIES of computing a solution to the Prandtl lifting line equation for large values of A/a_0 are well-known, at least to any investigators who have tried. In attempting to deduce the loading over straight-tapered wings, like those used on sailplanes, the author has used an iterative method by which the n^{th} approximation to the downwash is obtained by a numerical integration based on the $(n-1)^{th}$ approximation to the distribution of circulation. The main difficulty here is essentially one of making a good initial guess of circulation for the first approximation to the downwash.

The technique eventually established for making this initial guess, which led to a reasonably rapid convergence of the iteration, was merely to assume that the circulation varied in proportion to the local chord except close to the tips (to be precise, the region distance $0{\cdot}05\ a_0c_t$ from them), where the circulation was supposed to decay elliptically to zero. However, in making a systematic study of the effects of taper, it was possible to modify progressively both the shape of this circulation distribution near the tips, and its extent, in the light of fully iterated solutions for wings of slightly different taper ratios, so greatly facilitating the convergence of the process.

NOTATION

a	lift curve slope of wing
a_0	sectional lift curve slope
c	local chord
c_L	local lift coefficient
c_t	tip chord
k	induced drag factor
w	downwash velocity
y	distance spanwise from root
A	aspect ratio
C_L, C_{Di}	lift and induced drag coefficients
S	wing area
V	speed of motion of wing
α	local incidence relative to sectional no-lift line
β	defined by equation (6)
$\delta=k-1$	
τ	defined by equation (3)

The numerical integration of the downwash integral was based on well-known quadrature formulae using a linear spacing of 58 ordinates extending over the greater part of the span, and a closer linear spacing of ten ordinates over the region within a distance of $0{\cdot}25\ a_0c_t$ of the tips. The downwash was evaluated at points mid-way between these ordinates, and the circulation distribution thus derived was differenced to obtain values of the rate of change of circulation at the intermediate points for the calculation of the next approximation to the downwash. A special quadrature formula was used for the region of the tips, and to cover the range of six points in the neighbourhood of the singularity of the downwash integral.

In calculating the first approximation to downwash, it was also necessary to arrange that the assumed circulation changed smoothly at the kink in the plan form (associated with straight taper). In effect, the approximation made was that the rate of change of circulation at the kink was intermediate between that assumed to exist on either side. Thus, in the case of a kink on the centre line, the circulation was there assumed to be a maximum.

Plan forms considered varied in taper ratio between zero and one half, and various lengths of constant chord centre section were also considered. Iterations were repeated until the values of τ repeated within an accuracy of 0·005. Owing to the systematic approach, whereas a large number of iterations were necessary for the first calculations, only two were usually needed for later ones. The value of A/a_0 chosen was five, and both wing incidence and a_0 were assumed constant over the span.

The value of τ is defined (as by Glauert) from the formula for the lift curve slope:—

$$a=a_0\Big/\left\{1+\frac{a_0}{\pi A}(1+\tau)\right\}$$

The values in Table I show that τ is considerably larger for this aspect ratio (of $5a_0$) than the values calculated by Glauert (for $A=a_0$), but that a region of constant chord up to 0·5 or 0·6 of the span brings a significant reduction. This is, of course, quite plausible as the shape produced is more like the elliptic plan, for which $\tau=0$ (whatever the aspect ratio).

The prime intention of the computation was that values of δ be calculated, where $k=1+\delta$ is the induced drag factor. However, it was not before the point of no return had been reached in the calculation that the unfortunate fact was discovered that, for larger ratios of tip to root chord, the value of δ was not settling down in iteration with the same speed as τ. According to theory, δ must be less than τ, but should only differ substantially from it

TABLE I

VALUES OF τ FOR VARIOUS WIDTHS OF CONSTANT CHORD CENTRE SECTION AND TAPER RATIOS ($A/a_0=5$)

(*Width of central constant chord region*)/*span*	(*Tip chord*/*root chord*)						
	0*	0·1	0·2	0·25	0·333	0·4	0·5
0·0	1·520	1·289	1·183	1·159	1·145	1·150	1·177
0·1	1·477	1·270	1·174	1·150	1·136	1·139	1·161
0·2	1·413	1·244	1·156	1·134	1·121	1·125	1·149
0·3	1·346	1·204	1·137	1·122	1·109	1·114	1·141
0·4	1·288	1·175	1·117	1·103	1·100	1·104	1·136
0·5	1·246	1·148	1·104	1·094	1·092	1·102	1·135
0·6	1·215	1·143	1·104	1·100	1·100	1·112	1·139
0·7	1·202	1·146	1·118	1·114	1·122	1·129	1·157

*First approximation only.

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TABLE II

VALUES OF δ FOR VARIOUS WIDTHS OF CONSTANT CHORD CENTRE SECTION AND TAPER RATIOS ($A/a_0=5$)

(*Width of central constant chord region*)/*span*	(*Tip chord/root chord*)						
	0*	0·1	0·2	0·25	0·333	0·4	0·5
0·0	1·520	1·281	1·155	1·119	1·083	1·068	1·066
0·1	1·477	1·263	1·150	1·114	1·079	1·064	1·057
0·2	1·413	1·238	1·134	1·102	1·069	1·056	1·051
0·3	1·346	1·199	1·118	1·093	1·062	1·050	1·049
0·4	1·288	1·170	1·100	1·077	1·057	1·044	1·049
0·5	1·246	1·144	1·088	1·070	1·052	1·047	1·053
0·6	1·215	1 139	1·090	1·078	1·063	1·060	1·062
0·7	1·202	1·143	1·105	1·094	1·088	1·081	1·084

*First approximation only.

(within the accuracy of the lifting line approximation) due to the contribution of induced drag from the immediate locality of the tips; it is hoped therefore that the mistake in the technique may lie only in the numerical integration of induced drag due to an inadequate spacing of ordinates at the tip rather than in inadequate perseverence with successive iteration. On the other hand, it did not seem reasonable to take more ordinates closer to the tips, as already there was one within roughly ten per cent of the local chord from them, and plainly the actual tip shape used on a practical wing might differ substantially within this region from the idealised square-cut shape assumed.

Despite this doubt about their reliability, the values of δ obtained from the last iterated solution for the circulation distribution are quoted in Table II, and though lower than the values of τ, they are nevertheless still high compared with values for ordinary aspect ratios.

Incidentally, the fact that $\delta \leqslant \tau$ seems not to be generally realised and a proof is given in the Appendix; it applies only to untwisted wings, and the equality applies only to wings of elliptic loadings (for which $\delta=\tau=0$). The fact that Glauert's values of δ and τ are not always in accord with this inequality must be a reflection upon the accuracy of the numerical technique he used.

APPENDIX

PROOF THAT $\delta \leqslant \tau$ FOR UNTWISTED WINGS

The lifting line equation of Prandtl gives

$$c_L = a_0\alpha - a_0\,(w/V) \quad . \quad . \quad . \quad (1)$$

Denoting by barred quantities the mean values taken over the wing area, that is, putting

$$\bar{z}=\frac{1}{S}\int_{-s}^{+s} zc\,dy$$

where z is any function of y, it follows that the lift coefficient of the wing is, from (1)

$$C_L=\bar{c}_L=\overline{a_0\alpha}-\overline{(a_0 w)}/V \quad . \quad . \quad (2)$$

If we define τ by

$$C_L=\overline{a_0\alpha}\Big/\left\{1+\frac{\bar{a}_0}{\pi A}(1+\tau)\right\} \quad . \quad . \quad (3)$$

it follows from (2) that

$$\overline{a_0 w}/V=\bar{a}_0\,\overline{(a_0\alpha)}\,(1+\tau)\Big/\left[\pi A+(1+\tau)\,\bar{a}_0\right] \quad (4)$$

$$=\bar{a}_0 C_L\,(1+\tau)\Big/(\pi A).$$

The induced drag coefficient is, again using (1),

$$C_{Di}=\overline{c_L w}/V=\overline{a_0\alpha w}/V-\overline{a_0 w^2}/V^2 \quad . \quad (5)$$

Thus, if we place $\beta=\bar{a}_0\,\overline{(a_0 w^2)}\Big/\overline{(a_0 w)}^2 \quad . \quad . \quad (6)$

and take α as constant across the span, from (5) and (6)

$$1+\delta=k=\frac{C_{Di}\pi A}{C_L}=\frac{\pi A\alpha}{C_L^2}\,\frac{\overline{a_0 w}}{V}\left\{1-\beta\,\frac{\overline{a_0 w}}{\bar{a}_0 V\alpha}\right\} \quad (7)$$

Substituting from (4), it follows that

$$1+\delta=\frac{\bar{a}_0\,(1+\tau)^2}{\pi A}\left\{\frac{\bar{a}_0 V\alpha}{\overline{a_0 w}}-\beta\right\}$$

$$=\frac{\bar{a}_0\,(1+\tau)^2}{\pi A}\left[\frac{\pi A}{(1+\tau)\,\bar{a}_0}+(1-\beta)\right]$$

that is $$\delta=\tau-(\beta-1)\,(1+\tau)^2\,\frac{\bar{a}_0}{\pi A} \quad . \quad . \quad . \quad (8)$$

It follows from Cauchy's inequality that β is, by its definition in (6) greater than unity, unless w is constant across the span when $\beta=1$. This latter exception is the familiar condition of elliptic loading for which $\delta=\tau=0$; otherwise we see that $\tau>\delta>0$. The value of β tends to increase in proportion to aspect ratio as $A\longrightarrow\infty$, since $(w/V\alpha)$ is generally of unit order only over a region of the order of the tip chord from each tip.

Approximate Solution of the "Inverse Problem" of Boundary Layer Theory

by

P. BRADSHAW, B.A.

(*Aerodynamics Division, National Physical Laboratory*)

EXISTING APPROXIMATE FORMULAE for the thickness of laminar and turbulent boundary layers are used to derive a method of calculating the free-stream velocity distribution corresponding to a given variation of shape parameter.

Thwaites[1] has given the formula

$$\frac{\theta^2}{\nu}=\frac{0{\cdot}45}{u^6}\int_{x=0} u^5\,dx \quad . \quad . \quad . \quad (1)$$

for the momentum thickness of a laminar boundary layer with free-stream velocity $u\,(x)$. This is the integral form of the empirical equation

$$u\frac{d}{dx}\left(\frac{\theta^2}{\nu}\right)=0{\cdot}45-6\frac{\theta^2}{\nu}\frac{du}{dx}. \quad . \quad . \quad (2)$$

$\frac{\theta^2}{\nu}\frac{du}{dx}$ is the profile shape parameter used in the Pohlhausen method (described in Ref. 2), which assumes that profiles with a given value of $\frac{\theta^2}{\nu}\frac{du}{dx}$ are similar.

From equation (1) we have

$$\frac{\theta^2}{\nu}\frac{du}{dx}=\frac{0{\cdot}45}{u^6}\frac{du}{dx}\int_0 u^5\,dx \quad . \quad . \quad (3)$$

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Putting $\frac{\theta^2}{\nu}\frac{du}{dx}=\lambda$ and $\int_0 u^5\,dx=V$, we obtain

$$VV''=\frac{\lambda}{0{\cdot}09}V'^2 \quad . \quad . \quad (4)$$

which is an equation for the free-stream velocity in terms of λ.

Garner[3] and other workers, have given a similar quadrature formula for the turbulent boundary layer

$$\theta\left(\frac{u\theta}{\nu}\right)^{1/n}=\frac{a}{u^b}\int_0^x u^b\,dx \quad . \quad . \quad (5)$$

where $a=\frac{n+1}{n}\alpha$ and $b=\frac{n+1}{n}(H+2)-\frac{1}{n}$.

This formula is derived from the momentum integral equation and an empirical skin friction formula

$$\frac{\tau_0}{\rho u^2}=\alpha\left(\frac{u\theta}{\nu}\right)^{-1/n} \quad . \quad . \quad . \quad . \quad (6)$$

Garner's values for the constants using Falkner's data correlation are $n=6$, $\alpha=0{\cdot}0065$, $H=1{\cdot}4$. A special case of the shape parameter introduced by Clauser[4] for the turbulent case, using (6), is

$$L=\frac{\theta}{\tau_0}\frac{dp}{dx}$$

$$=-\frac{(n+1)/n}{U^{b+1}}\frac{du}{dx}\int_0 u^b\,dx \quad . \quad (7)$$

Putting $\int u^b\,dx=W$, (7) becomes

$$WW''=-\frac{n}{n+1}\,b\,L\,W'^2 \quad . \quad . \quad (8)$$

which is similar to (4).

The solution of $ff''=gf'^2$, where $g(x)$ is known, is

$$f=\exp\int\frac{dx}{\int(1-g)\,dx}$$

so that from (4) and (8), V and W, and hence u can be calculated for any given variation of the shape parameters λ and L.

In particular, when the parameters take constant values,

we have $u\propto x^{\lambda/(0{\cdot}45-8\lambda)}$ from (4)
and $u\propto x^{-L/[(n+1/n)+bL]}$ from (5).

Thus we recover the results of Falkner and Skan[5] and Townsend[6] that similar profiles are obtained in both the laminar and turbulent cases for a power law variation of free-stream velocity.

More generally, the method can be used in the design of aerofoils to have a specified boundary layer development. For instance, an aerofoil which just avoids laminar separation can be designed by taking $\lambda=0{\cdot}075-0{\cdot}175\,x$ so that λ changes linearly from 0·075, the stagnation value, at the leading edge ($x=0$), to $-0{\cdot}1$, the approximate separation value, at the trailing edge, $x=1$. The solution for the velocity is

$$u\propto\frac{x}{(x+0{\cdot}171)^{7/5}}$$

which is plotted, normalised with its maximum value, in Fig. 1.

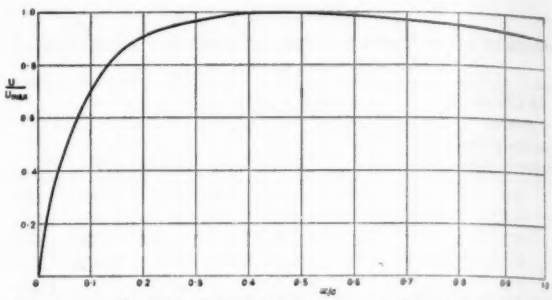

FIGURE 1. Velocity distribution for aerofoil designed to avoid laminar separation.

The formula (5) for the turbulent layer becomes highly inaccurate near separation so that its use is restricted to favourable or fairly mild adverse pressure gradients. It should nevertheless be useful for calculating in advance the free-stream velocity distribution required to produce a given test boundary layer for research purposes.

ACKNOWLEDGMENT

The work described has been done as part of the research programme of the National Physical Laboratory, and this note is published by permission of the Director.

The author is grateful to Dr. L. A. Segel for pointing out that $ff''=gf'^2$ could be easily solved for a general function g.

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The Subsonic Ram-Jet as an Aid to Technical Education

by

P. A. HILTON, A.F.R.Ae.S.

FOR some years the author has been interested in subsonic ram-jets as a means of helicopter rotor tip propulsion and has done a considerable amount of experimental work with this end in view. Most of the effort has been concentrated on producing engines to operate at the lower end of the speed range as it was thought that, however simple a ram-jet may be, this advantage is lost when other means of propulsion are needed for starting purposes.

The first objective, achieved in the autumn of 1958, was to be able to start an engine and for it to become self-

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accelerating from a hand swing on a spinning rig. The next step, to produce an engine suitable for helicopter use, is a long task and work is still continuing.

Much needed help on static test work was given in the early stages by the College of Aeronautics, Cranfield, and the National Gas Turbine Establishment, Pyestock, and the prototype propane gas engine has been retained by the College of Aeronautics where it has been used for the past three years as a demonstration model.

During the static test programme at Cranfield and Pyestock it became clear that an exceedingly useful item of demonstration equipment had been found which was worthy of further investigation, not only as an example of aircraft propulsion but also for the demonstration of basic thermodynamics, gas dynamics and combustion.

Enquiries at several universities and technical schools revealed considerable interest, but in most cases they were unable to make use of this equipment because of lack of suitable air supply. Even universities with high speed wind tunnels have found this difficult without considerable modification, so that for a while efforts were concentrated on achieving satisfactory operation with much reduced air supply power requirements.

It must be appreciated that to push air through a 3½ in. diameter orifice at 800 ft./sec. requires over 100 h.p. and at 500 ft./sec. approximately 45 h.p.

By using the experience gained on low speed work an engine has now been produced which operates in an air stream of 300 ft./sec. flowing through a 3 in. diameter orifice; this requires only 8 h.p.

To control the engine and to measure its performance a special test stand has been developed which carries all the necessary equipment for this purpose. The flame-holding baffle system and the fuel injectors have also been so designed as to permit a Pitot-static pressure probe to pass along the axis and enable a record to be made of the pressure variations taking place throughout the complete operating cycle. With readings taken of the engine running hot and cold the air mass flow can be determined and the gas velocities and temperatures calculated.

The ram-jet is the simplest form of heat engine, and having no moving parts obviates the need for a lubrication system. When propane is used as fuel no pumps or filters are required, the feed being effected by vapour pressure and complete control achieved by a single valve.

The basic principles common to all heat engines, *i.e.* compression of air or gas, addition of heat through combustion, and the subsequent performance of work through an expansion process are embodied in the ram-jet.

GENERAL DESCRIPTION

The complete equipment consists of the engine on the test stand, the air supply blower, and an exhaust deflector. Fig. 1 is a rear view showing the engine on its thrust linkage and Fig. 2 shows the rear view diagrammatically.

The blower is a two-stage centrifugal fan which supplies approximately 1,000 cu. ft./min. at 1 lb./in.² and is driven by an 8 h.p. electric motor. A 36 in. length of ducting between the blower and the nozzle ensures a good velocity distribution over the engine.

The engine is mounted on a hydraulically damped linkage and is free to move fore and aft over a small range between limit stops. Direct loading by spring balances is applied to maintain the engine floating freely in the neutral position. Standard pattern balances of 0-10 lb. are used and a wide range of similar instruments can be used to cover a range of from 0-400 lb. without modification to the test stand, if this is used for other purposes.

Propane gas is used for fuel. This is supplied by four 75 lb. cylinders located either outside the laboratory or in an adjacent room. Regulators control the pressure to 40 lb./in.² and are located next to the cylinders. The gas is then piped to the test stand where it is controlled by the main valve in the centre of the panel. The rate of fuel flow is measured by a Rotameter and a thermometer and two pressure gauges register the temperature and the supply and delivery pressures.

A special water-cooled Pitot-static pressure probe has been developed which is mounted on a small wheeled trolley. Operated by a hand wheel on the control panel, the probe can be made to pass along the centre line of the engine. A circular indicator is also provided which determines the exact location of the sensing holes with reference to the engine. Glass tube manometers are mounted on the panel to measure air supply total pressure, as well as probe total and static pressures. (*See* Fig. 3).

The exhaust deflector was originally designed only to disperse the hot gases, but has been found in practice to permit close observation of the combustion zone. It takes the form of a stainless steel tube of 11·4 in. diameter and 24 in. long. At the farthest end a number of deflector vanes set at 45° form a cascade and between these vanes a clear unobstructed view is possible from as close as 24 in. from the end of the tube.

Ignition is provided by means of a special sparking plug and trembler coil powered by a small dry battery.

The engine, which is 5 in. in diameter and 15 in. long is of circular section and consists of two main parts. These are the Intake and Tailpipe assemblies, both bolted to the main mounting ring. The intake assembly and fuel injection system are of stainless steel, whereas the tailpipe and flame-holding baffles are of nimonic material. Performance is of the order of 3-3½ lb. net thrust at 300 ft./sec.

Apparatus for exhaust gas analysis is found in most Mechanical Engineering Laboratories so this is not at present provided, but its addition is simple and its use substantially increases the scope of the whole equipment.

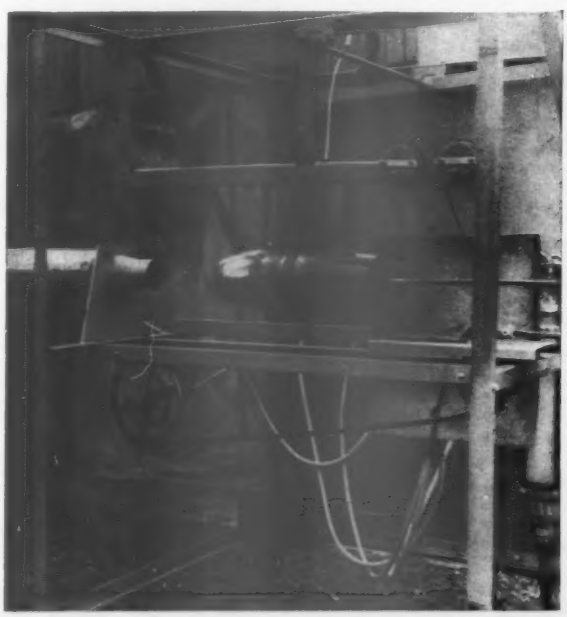

FIGURE 1. Rear view, showing the engine on the test stand.

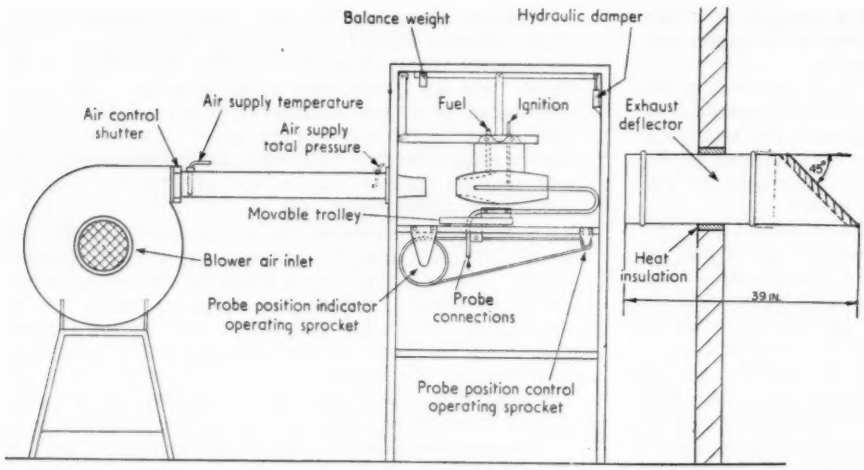

FIGURE 2. Diagrammatic rear view of equipment.

APPLICATIONS

The following are some of the demonstrations which can be carried out with this equipment:

(1) Principles of dynamics: forward thrust produced by increase in rearwardly directed gas velocity through the engine.

(2) Principles of thermodynamics: kinetic energy added to gas flow by the addition of heat.

(3) Principles of operation of ram-jet: ram compression followed by the addition of heat at the high pressure end of operating cycle produces thrust.

(4) Characteristics of the components of all continuous flow engines: intake, ignition and combustion systems, and exhaust nozzle.

(5) Tests on air intakes alone, using the rig as an open wind tunnel.

(6) Tests on ignition and combustion systems alone. Direct coupling to the air supply is possible. The Pitot-static probe is used for sampling combustion gases.

(7) Tests on exhaust systems and nozzles alone, with or without combustion.

(8) The rig can be made to produce high temperature gas streams for heat transfer and experiments on materials behaviour.

(9) The rig is an ideal item for experiments in conjunction with high temperature measurement equipment, as well as being a check on performance calculations.

(10) The effect of flame-holding baffles on combustion stability can be clearly seen, not only through the intake but also through the exhaust deflector.

In addition to the work described so far in this note the rig may be used to supply air, fuel, and ignition for use on other combustion rigs.

CONCLUSIONS

During all low speed work greater emphasis has been placed on achieving high performance than on good specific fuel consumption, bearing in mind that low speed operation on a helicopter would always be under conditions of acceleration and would be of short duration. This policy has proved invaluable in the development of engines for demonstration purposes where the main criterion is the ability to operate with moderate air supplies.

With the air supply requiring only 8 h.p. this equipment is proving acceptable to engineering laboratories.

We believe this to be the first time that equipment has been made available which enables a student to undertake performance studies of a complete jet engine under simulated flight conditions.

Imperial College of Science and Technology, London, has installed a subsonic ram-jet in its Aeronautical Laboratory but it is too early to report on its use.

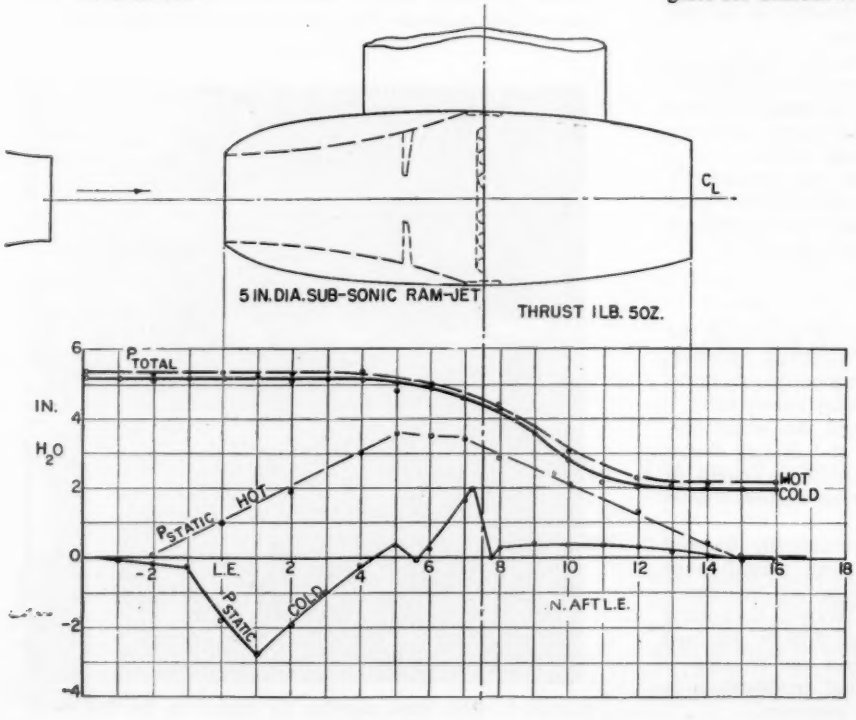

FIGURE 3. Pressures recorded with Pitot-static probe. The diagram was plotted from actual results of a low speed experiment with an air speed of below 150 ft./sec. An interesting feature is the static pressure rise with the engine running hot which starts 2 in. in front of the leading edge of the intake.

Free Vibration and Hysteretic Damping

by

P. LANCASTER

(Department of Mathematics, University of Malaya, Singapore.)

I WOULD LIKE to add yet another note to those already published on the notions of viscous and hysteretic damping in a simple oscillator[1, 2, 3, 4]. In particular, I would like to hammer a nail into the coffin of the so-called "complex stiffness."

NOTATION

F amplitude of applied force
h coefficient of hysteretic damping
$i=\sqrt{(-1)}$
k stiffness
M mass
n circular frequency
R amplitude of displacement
t time
x displacement
η undamped natural frequency
κ viscous damping coefficient
λ measure of rate of decay of free vibrations
μ dimensionless measure of damping$=h/k$
$\tau=h/2\sqrt{(kM)}$
ω frequency of excitation

One of the features which hysteretic damping may be defined to possess is the property that the energy loss per cycle (in sinusoidal motion) is independent of the frequency of oscillation, ω. This property is derived from some experimental evidence[5]. It is shown in Reference 1 that this behaviour is reproduced by the particular integral of the equation

$$M\ddot{x}+\frac{h}{\omega}\dot{x}+kx=Fe^{i\omega t}.$$

This leads us to examine the equation

$$M\ddot{x}+\frac{h}{\omega}\dot{x}+kx=0 \quad . \quad . \quad . \quad (1)$$

for a solution of the problem of free vibrations. Differences in analysis and opinion depend on the interpretation now put on ω, for it can no longer be correlated with the frequency of a given sinusoidal motion.

The idea of a complex stiffness is reproduced if we look for a solution in the form $x=Re^{i\omega t}$, where it is understood that ω may be complex. In this case it is customary to write the governing equation as

$$M\ddot{x}+k(1+i\mu)x=0, \quad . \quad . \quad (2)$$

where $\mu=h/k$. This leads to only one solution that can be entertained for physical reasons, namely

$$x=Re^{-\alpha t}.e^{i\beta t},$$

where $\alpha=\left\{\frac{k[\sqrt{(1+\mu^2)}-1]}{2M}\right\}^{\frac{1}{2}}$,

and $\beta=\left\{\frac{k[\sqrt{(1+\mu^2)}+1]}{2M}\right\}^{\frac{1}{2}}$.

The trouble with this solution is that it cannot be given a satisfactory physical interpretation. The reason for this is that although this complex solution is valid, neither the real nor imaginary parts of it are separately solutions. In fact Bishop's equation (23) simply is not a solution of the original differential equation. A similar criticism may be made of a paper by Myklestad[3]. Clearly, the significance of the device of looking for a solution in the form $x=Re^{i\omega t}$ depends on being able to interpret the answers in terms of real functions involving sine and cosine factors. The presence of complex coefficients in equations (1) and (2) renders this impossible.

If we follow Reid[2] in defining a hysteretic damping force as being in phase with velocity (which is not true in this case), then two physically sensible alternatives are open. Assuming that there is a solution of the form $x=Re^{(\lambda+in)t}$, where λ and n are real, we may:

(*a*) Identify ω in (1) with the circular frequency, n, and investigate

$$M\ddot{x}+\frac{h}{n}\dot{x}+kx=0, \quad . \quad . \quad (3)$$

as suggested in Ref. 1, which gives the detailed solution.

(*b*) Identify ω in (1) with the modulus of the "complex frequency" $(\lambda+in)$ and investigate

$$M\ddot{x}+\frac{h}{\sqrt{(\lambda^2+n^2)}}\dot{x}+kx=0, \quad . \quad . \quad (4)$$

as suggested in Ref. 2, where details of the solution are given. This formulation implies that the damping force is proportional to the displacement as well as being in phase with the velocity.

Since the coefficients of equations (3) and (4) are real, it follows that the real and imaginary parts of $Re^{(\lambda+in)t}$ (once satisfactory values of λ and n have been determined), will themselves be solutions. Hence the usual physical interpretation can be applied, as for viscous damping.

A surprisingly neat result is obtained if we consider a system which contains *both* viscous damping and hysteretic damping of type (*b*). We suppose the viscous damping force per unit mass to be $2\kappa\dot{x}$, put $(k/M)=\eta^2$ (the square of the undamped natural frequency), and write $\tau=h/2\sqrt{(kM)}$. Then κ, τ, and η have the same dimensions, and the equation of motion is

$$\ddot{x}+\left\{2\kappa+2\tau\frac{\eta}{\sqrt{(\lambda^2+n^2)}}\right\}\dot{x}+\eta^2x=0. \quad (5)$$

It is found that a solution which is proportional to $e^{(\lambda+in)t}$ is possible if

$$\lambda=-(\kappa+\tau),$$

and

$$n^2=\eta^2-(\kappa+\tau)^2.$$

If we combine viscous damping with hysteretic damping of type (*a*) and consider

$$\ddot{x}+\left(2\kappa+\frac{2\tau\eta}{n}\right)\dot{x}+\eta^2x=0, \quad . \quad . \quad (6)$$

we do not get a simple explicit solution.

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The first extant Branch of the Society is that of Coventry, formed in 1925, which was the subject of last month's issue of this page. The second is Yeovil.

THE Branch first came into being at the then Westland Aircraft Works Ltd., in 1926 under the title of "The Westland Aircraft Society" and was from the first, affiliated to the Royal Aeronautical Society.

It was sponsored by Mr. V. S. Gaunt as Chairman, Mr. H. J. Penrose the present Sales Manager and former Chief Test Pilot, as Secretary, and the late Mr. R. A. Bruce who was then Managing Director of Westlands, as President.

The original aim was to give useful technical background to the various personnel in the factory, and the first lectures were "internal" and concerned mostly with practical problems.

But this phase quickly developed into lectures covering a much wider field and which were given by visiting lecturers representing other aircraft firms, or with "know-how" in some facet of engineering practice in which the members of the Branch had an interest.

Meetings took place every week at the Choughs Hotel, which allowed the lecturer to be dined there beforehand and the audience to assemble and enjoy the comfort of the bar until the lecturer was seen to be moving up the stairs to the lecture room, a most satisfactory arrangement, which assisted in keeping up a steady weekly attendance. (The meetings also stopped promptly at 9.30 p.m.!)

The Branch flourished in this manner right up to the outbreak of the War when activities were necessarily suspended until the cessation of hostilities.

By this time Westland Aircraft had expanded and the family atmosphere had been largely submerged, for the first year's post war membership was over 400.

The original venue was now no longer large enough and there were so many other activities that the weekly meetings were made three-weekly and a suitable school hall became the Branch's lecture theatre.

Since that time the Branch strength has stabilised at about 250 members; about ten or twelve meetings are held each winter season which include the Henson and Stringfellow Memorial Lecture now in its fifth year. The latest Henson and Stringfellow Lecture was given on the 29th February 1960, by Mr. D. Keith-Lucas, Chief Designer of Short Brothers and Harland, on the subject of V.T.O.L., based on the experience of the S.C.1. The lecturer, not satisfied with a purely theoretical approach to stability and control, used a manual control mechanism that even defeated the piloting abilities of Peter Twiss until the various damping devices had been connected. The Lecture was very well attended, with representatives from Bristol, Boscombe Down, Cheltenham and Gloucester, Swindon and from as far away as Derby. No evidence of yet further mergers should be inferred from this representation.

While the original membership of the Branch was almost wholly from Westland Aircraft, this is now shared with Normalair Limited, a commercial subsidiary and geographical partner at Yeovil. This partnership is reflected in the Branch by a dual Chairmanship of Mr. D. L. Hollis Williams, F.R.Ae.S. from Westlands and Dr. E. W. Still, F.R.Ae.S. from Normalair, under the Presidency of Mr. E. C. Wheeldon, Managing Director of Westlands.

The Secretary was, is and apparently always will be, Mr. L. A. Lansdowne, A.F.R.Ae.S., who has served so well in this office for twenty years—or from the time of the Lysander to the present galaxy which includes the (Bristol) 192, the (Fairey) Rotodyne and the Westminster. These mergers must presumably have some influence on Branches of the Society, and it will be interesting to see what happens. On reflection, it was magnanimous of Yeovil to invite Mr. Keith-Lucas to dissertate on "jet-lift"—perhaps the next one should be on ballooning as V.T.O.L.?

Messrs. Henson and Stringfellow would certainly, 100 years later, be astonished at the achievement of this Somerset industry and pleased with so active a Society that pays them annual tribute.

Branch News

Also by way of annual tribute, the Seventh Barnwell Memorial Lecture was given at Bristol on the 10th March by Sir Roy Fedden on "The First 25 Years of Bristol Aero Engines." This, too, was a memorable occasion, made historic by a brilliant Lecture, and the presence of many famous figures in aviation who together spanned almost the whole history of British aviation—Lord Sempill, Sir George Dowty, Captain Pritchard, Dr. Moult (President-Elect), Mr. Volkert, Dr. Lachmann, Mr. Frise, Major Oliver Stewart, Mr. Thurstan James, Major Bulman, Sir Alfred Pugsley, Air Commodore Banks, Mr. C. F. Uwins, Dr. A. E. Russell, Sir Reginald Verdon Smith, and many old friends of Bristol and visitors from other Branches. Professor Collar, Vice-President of the Society and Member of Council, was in the Chair as Branch President and, playing an accomplished part as both host and guest, Mr. Peter Masefield, President of the Society. Eighty guests sat down to Dinner.

Sir Roy Fedden was classically flanked by Hercules and Jupiter, and as a fitting reminder of the man who was being honoured, Captain Barnwell's Viale engine (mentioned in last month's JOURNAL) was also on view.

From Bristol, too, comes news of a collaboration by the Branch Secretary and the President of the Society, Mr. Peter Masefield, in a television programme broadcast by T.W.W. "Wings in the West" is to be shown on Easter Monday and it is hoped will later be broadcast on the national network. The half hour programme is an aerial pilgrimage (by Auster and a certain well known Chipmunk) to those places in the West that saw the history of aviation and includes Chard (Henson and Stringfellow) and the more obvious connections with Cardiff, Bristol, Yeovil, Cheltenham, Gloucester and Yate, together with some less obvious historic connections. Some aircraft are to be shown which were previously unknown.

LONDON does not qualify as a Branch, but an item of some interest is the recent journeys of Dr. Ballantyne to (strange coincidence) Scotland. He is reported, from usually reliable sources, to have been carrying heraldic devices to Glasgow, which, after carving in wood, will become the crests (of the Branch towns and cities) for the new Lecture Hall. While the Society has its famous crest, is there not a motto?

NOTE—Will Branch Secretaries *please* forward items of news to the Editor, Royal Aeronautical Society, 4 Hamilton Place, W.1, for forwarding to G.W-W.

Graduates' and Students' Section

Hovercraft

On 9th March we were given a most interesting talk on the Hovercraft by W. J. Eggington of Hovercraft Development Ltd. He first showed a film which illustrated the research work and model trials carried out before the full size design could be started, and followed the project through until flight trials were in progress with the Saro SR-N1.

It was made clear that the Hovercraft is a displacement vehicle in the same way as a land or water-borne vehicle. These displace the ground or water, but the Hovercraft does it indirectly through a cushion of air on which it travels with greatly reduced friction. This is more apparent over water when it can be seen that the air is producing an annular depression in the water.

That the lift is not from accelerating the air downwards is shown by the total vertical thrust of the SR-N1 being 800 lb. for a weight of 8,500 lb.

In fact there is great advantage in size since the power required is proportional to the length of the peripheral slot, which varies with the radius directly, while the weight will tend to vary with the area, that is the square of the radius.

Mr. Eggington discussed the various different methods available for lifting such craft and showed why the choice was made of two circular slots with the air from the outer slot being directed *inwards* at 30°.

Problems peculiar to the Hovercraft were the low side force available from the vertical thrust for manoeuvring due to the maximum useable tilt of one degree, the stability over waves of varying heights and lengths (which brought in an unusual aeronautical term, "stability of heave") and the effect of spray thrown up by the air cushion.

Hover height had to be half wave height so long as the wave length was less than the length of the craft beyond which the craft would follow the wave. Even allowing for maximum wave heights of 60 ft., which could be met in the Atlantic, it was calculated that the accelerations experienced would be low due to the long wave length, and values would be about 0·1 *g*.

There was no reason why versions should not be developed having bodies shaped to give aerodynamic lift, when the craft becomes an aerofoil with no lower surface, and speeds up to 250 m.p.h. might be possible, although the lecturer felt that the most useful field lay in the speed range up to about 150 knots, which was the limit for the cushion pressure to remain higher than the free stream stagnation pressure.

Answers to questions at the end of the talk also covered the stressing cares considered and "engine out" performance and we were left in no doubt that we would be hearing a lot more of the Hovercraft in the future.—P.T.R.

Cricket—Committee v. The Rest

Resulting from a suggestion at the A.G.M. a light-hearted cricket match has been arranged between the Committee and Mr. Moulton's XI representing The Rest. This will take place at the Handley Page Sports Ground, Cool Oak Lane, Hendon, at 7 p.m. on Friday 24th June. It will be followed by an informal dance which will take the place of the Summer Party which cannot be held at Hamilton Place this year, owing to the work on the new Lecture Hall.

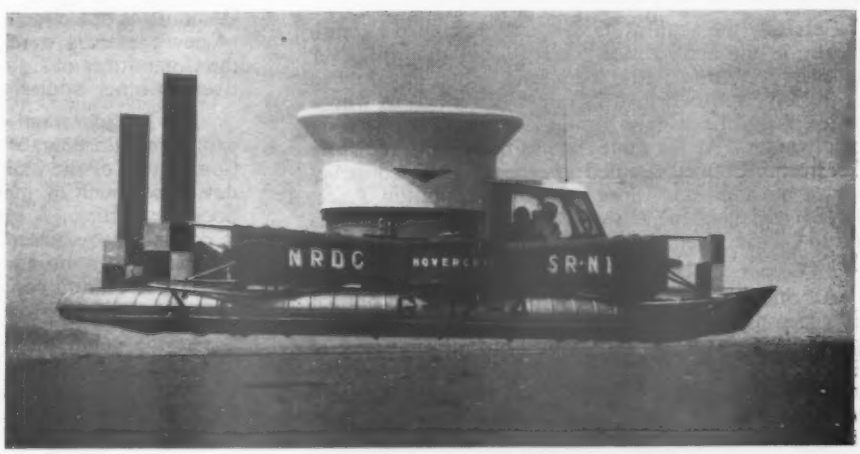
We hope that this will stimulate sufficient interest to form a cricket team to challenge Graduates from other professional bodies.

Those interested in playing should contact Mr. Moulton, c/o Queen Mary College, Mile End Road, E.1.

Future Visits

You are reminded of the Vickers visit on 21st May mentioned in the last issue. A visit to Guinness has been arranged for 5th November.

We have been invited to visit Blackburn and General Aircraft at Brough. We will arrange this if there is sufficient interest; it might be more suitable for members living in the Midlands. Please contact the Hon. Visits Secretary, N. R. Craddock, 5 Oxleay Road, Harrow, Middx., giving the time of year and day of week preferred.



The SR-N1 Hovercraft, built by Saunders-Roe Ltd. for the National Research Development Corporation.

Courtesy of Saunders-Roe Ltd.

Ninety-Fifth Annual Report of the Council 1959-1960

FIVE events of significance to the future marked the 94th year of the Society's existence:—

A decision was taken to build a lecture theatre for the Society at No. 4 Hamilton Place and, following the success of the appeal for funds, work was started on 5th October 1959.

The new By-Laws of the Society were approved by the Privy Council in January 1960—after several years of work upon their drafting by a Committee of Council.

During October 1959 the Seventh Anglo-American Conference was held with the Institute of the Aeronautical Sciences and the Canadian Aeronautical Institute in the United States and in Canada, and agreement was reached on the holding of the Eighth Conference in England in September 1961. These Conferences are now an established part of international aeronautical affairs and they do much to promote "hands across the sea."

In January 1960 the Helicopter Association of Great Britain voluntarily amalgamated with the Society and the new Rotorcraft Section of the Society was instituted, with the former Council of the Helicopter Association as its first Committee.

In January 1960 also, at long last, the Burnham Committee formally recognised the qualification of Associate Fellowship of the Royal Aeronautical Society. At the same time a Higher National Certificate in Aeronautical Engineering was inaugurated.

All these five events have afforded particular satisfaction to the President and Members of the Council of the Society—as, no doubt, they will do to the whole membership of the Society. All of them represent the results of long planning and endeavour. And all of them augur well for the future—in a year in which the total membership of the Society has achieved a new high level at 10,723 (on 31st December 1959).

Certainly the acquisition of a fully equipped Lecture Theatre in the aeronautical heart of London will, over the years, prove to be of increasing value, not only to the Society, but to British Aviation in general to whose service it will be widely available when not in use on Society affairs. At the same time as building the Lecture Theatre the Council decided to embark upon construction of an additional floor to No. 4 Hamilton Place, thereby replacing the office accommodation which has had to be sacrificed to provide a foyer for the Lecture Theatre.

All this work could not have been attempted but for the generous response to the Lecture Theatre Appeal, launched in May 1959, on the part of both members of the Society and Industry, at home and abroad. The President and Council take this opportunity of repeating their expressions of gratitude to all those who have subscribed.

During the construction work in the Society's headquarters some upheaval in staff arrangements has been inevitable and, for the period of a few months, the Technical Department is having to work in the Library. This has caused some temporary reduction in the Library services and the Council wish to apologise for such inconvenience as may be caused to Members on this account.

The new By-Laws carry forward in practical form all the aims and objects of the Society—at the same time incorporating such changes and improvements in procedure as have been found desirable over the years. They will now be completed by the changes made necessary by the welcome completion of the arrangements between the Society and the Helicopter Association of Great Britain.

This major event—the incorporation of the Helicopter Association with the Society—means that, subject to the agreement of a Special General Meeting of the Society—the name of the Helicopter Association will be included in the full title of the Society. The Council of the Society welcomes the new acquisition of strength and believes that the Rotorcraft Section will carry forward the traditions of the Helicopter Association in a manner which will further enhance all for which both bodies have worked for so long.

In addition to these events of so much long term significance, the year has been a period of substantial activity on many fronts. In particular the President and Council welcome the formation of additional specialised Groups—such as those on Man Powered Aircraft, on Agricultural Aviation and the Historical Group. At the same time the Technical Work of the Society has been pressed forward with increased activity while, among the Branches, a particularly successful year has been achieved.

Among many events in the Society's year, the Anniversary Luncheon on 12th January 1960 was outstanding; more than 400 were present, including the Minister of Aviation, Mr. Duncan Sandys.

At the beginning of the new Presidential Year all Committees of Council were reconstituted and a number of new members were invited to serve. A full list of the Committees of Council and the Society's representatives on other bodies appears on pages 250-1.

The President and Council take this opportunity of expressing their gratitude to all the members of the Committees of the main Society and the Branches who devote so much of their time to the well being of the Society's affairs. A great deal of work of the Society is conducted by these Committees and but for the time so freely given by so many ordinary members of the Society its affairs could not be conducted in the way that they have been.

At the same time, the President and Council are especially grateful for the devoted work of all the Staff of the Society in a year which has been more than usually difficult because of the upheavals resulting from the new building activities.

Thus the Society enters its 95th Year with renewed strength and vigour. The retiring President, Mr. Peter Masefield, and the Council, offer their good wishes to the President-Elect, Dr. Eric Moult, and all members for an even better year ahead.

The Council 1959-1960

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SIR GEORGE EDWARDS, C.B.E., B.Sc., F.R.Ae.S., Hon.F.I.A.S.
SIR ARNOLD HALL, M.A., F.R.S., F.R.Ae.S.

President-Elect

DR. E. S. MOULT, C.B.E., B.Sc.(Eng.), F.R.Ae.S., M.I.Mech.E.

Vice-Presidents

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SIR SYDNEY CAMM, C.B.E., F.R.Ae.S.
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H. H. GARDNER, B.Sc., F.R.Ae.S.
SIR HARRY M. GARNER, K.B.E., C.B., M.A., F.R.Ae.S.
D. KEITH-LUCAS, M.A., F.R.Ae.S., M.I.Mech.E.
M. B. MORGAN, C.B., M.A., F.R.Ae.S.
SQUADRON LEADER R. C. G. T. ROGERS, D.C.Ae., A.F.R.Ae.S., R.A.F.
A. A. RUBBRA, B.Sc., F.R.Ae.S., M.I.Mech.E.
B. S. SHENSTONE, M.A.Sc., F.R.Ae.S., F.C.A.I., A.F.I.A.S.
W. TYE, O.B.E., B.Sc., F.R.Ae.S.
T. A. WOLSTENHOLME, A.R.Ae.S.

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Secretary: A. M. BALLANTYNE, T.D., B.Sc.(Eng.), Ph.D., F.R.Ae.S, Hon.F.C.A.I., F.I.A.S.

Ex-Officio Members

A. V. CLEAVER, F.R.Ae.S., Chairman of the Astronautics and Guided Flight Section.
PROFESSOR J. A. J. BENNETT, D.Sc., Ph.D., F.R.Ae.S., Chairman of the Rotorcraft Section.
The Presidents of the Australian Division, the New Zealand Division and the Southern Africa Division.

Annual General Meeting

The 94th Annual General Meeting of the Society was held at 4 Hamilton Place, London W.1, on Thursday 7th May 1959, at which the Annual Report and Balance Sheets of the Royal Aeronautical Society and Aeronautical Trusts Limited for 1958 were approved. The Report and Balance Sheets were published in the April 1959 JOURNAL.

The President reported the following elections to fill the vacancies on the Council:—

*A. D. Baxter (*Fellow*)
Dr. W. Cawood (*Fellow*)
*Profesor A. R. Collar (*Fellow*)
*Sir Harry M. Garner (*Fellow*)
D. Keith-Lucas (*Fellow*)
A. A. Rubbra (*Fellow*)
B. S. Shenstone (*Fellow*)

*Re-elected

New Fellows 1959

The following elections to Fellowship were announced:—

Charles Bayly
Leslie H. Bedford
Raymond L. Bisplinghoff
Edward G. Broadbent
Edmond A. S. Brun
Tadeusz L. Ciastula
Edward C. Cornford
Noel Daum
Sir Vincent Z. de Ferranti
William D. Disbrey
Robert R. Duddy
Wladyslaw Fiszdon
Oliver L. L. Fitzwilliams
Robert H. Francis
Richard W. G. Gandy
Ferdinand B. Greatrex
Lionel Haworth
Albert W. Hotson
Olliver W. Humphreys
Richard J. Ifield
Francis E. Jones
Oscar P. Jones
Peter Lloyd
Sir Arthur W. B. McDonald
Arnold W. Morley
Wilfred N. Neat
Griffith G. Roberts
Henry Roberts
Norman C. S. Rutter
Edward R. Sharp
Albert G. Smith
Alec J. Tyndale-Biscoe
Jacques Valensi
Cedric O. Vernon
Eric J. Warlow-Davies
Henry R. Watson

The retiring President, Sir Arnold Hall, presented the Society's Prizes and Awards to the following recipients:—

The George Taylor (Australia) Gold Medal	H. L. Cox
The Pilcher Memorial Prize	A. W. Kitchenside
The Navigation Prize	C. M. Cade
The Usborne Memorial Prize	Dr. J. S. Przemieniecki
The J. E. Hodgson Prize	J. E. Allen
The Branch Prize	B. D. Blackwell
The Orville Wright Prize	Dr. D. A. Spence
The Simms Gold Medal	R. P. Probert

At the conclusion of the Meeting, Sir Arnold Hall inducted his successor, Mr. Peter G. Masefield, as the President of the Society for the year 1959/60.

Named Lectures

47TH WILBUR WRIGHT MEMORIAL LECTURE

The 47th Wilbur Wright Memorial Lecture was given by Mr. Charles J. McCarthy, S.B., F.I.A.S., Chairman of the Board, Chance Vought Aircraft Inc. on "Managing Aviation Technologies," on Thursday 14th May 1959. (*See* July 1959 JOURNAL).

THE FIFTEENTH BRITISH COMMONWEALTH LECTURE

The Fifteenth British Commonwealth Lecture was delivered on Thursday 19th November 1959, by Mr. W. P. Smith, M.B.E., B.A., F.R.I.C.S., Director, Fairey Air Surveys Ltd., on "Some Recent Progress in Air Survey with special reference to Newly-Developed Territories." (*See* January 1960 JOURNAL).

THE THIRD LANCHESTER MEMORIAL LECTURE

The Third Lanchester Memorial Lecture was delivered by Professor Dr. H. Schlichting, on "Some Developments in Boundary Layer Research in the Past Thirty Years," on Thursday 26th November 1959. (*See* February 1960 JOURNAL).

THE THIRTEENTH LOUIS BLÉRIOT LECTURE

The Thirteenth Louis Blériot Lecture was delivered in Paris on 2nd March 1960, by Dr. E. S. Moult, C.B.E., B.Sc.(Eng.). F.R.Ae.S., M.I.Mech.E., Technical Director of de Havilland Engine Co. Ltd., and President-Elect of the Royal Aeronautical Society. His subject was "Current Problems in Aero Engine Design." (To be published in the May 1960 JOURNAL).

Lectures

The following Lectures have been read before the Society in 1950/60:—

1959

Friday 4th September: Symposium on Operational Problems of Take-off and Landing.

Thursday 22nd October: ASTRONAUTICS AND GUIDED FLIGHT SECTION—Problems of Atmospheric Re-Entry. T. R. F. Nonweiler.

Tuesday 27th October: MAIN LECTURE—Aircraft Fatigue—A Survey of Current Thought. R. J. Atkinson.

Friday 30th October: MAN POWERED AIRCRAFT GROUP—INAUGURAL MEETING—Résumé of the Theory and Practice. Short talks given by H. B. Irving, Dr. D. R. Wilkie, T. R. F. Nonweiler, B. S. Shenstone and J. L. Nayler.

Friday 13th November: AGRICULTURAL AVIATION GROUP—General Discussion on the International Conference at Cranfield.

Tuesday 17th November: LECTURE—Heat and Mass Transfer in Aeronautical Engineering. Professor D. B. Spalding.

Friday 27th November: MAN POWERED AIRCRAFT GROUP—Man as an Aero Engine. Dr. D. R. Wilkie.

Tuesday 1st December: LECTURE—Transonic Flow over Swept Wings. E. W. E. Rogers, and Dr. I. M. Hall.

Thursday 3rd December: MAIN LECTURE AT GLOUCESTER AND CHELTENHAM BRANCH—Some Servo Mechanisms for Supersonic Aircraft. S. G. Glaze.

Tuesday 8th December: LECTURE—Some Practical Aspects of Compressor Blade Vibration. Dr. E. K. Armstrong and R. E. Stevenson.

Friday 11th December: All Day Discussion on Flight Safety.

Friday 11th December: AGRICULTURAL AVIATION GROUP—Aerial Operations Planning in the United Kingdom. Peter King.

Thursday 17th December: LECTURE—Engineering Features of Rear Engine Installations in Transport Aircraft. E. S. Allwright.

1960

Thursday 7th January: YOUNG PEOPLE'S LECTURE—Flying versus the Human Machine—A Lecture-Demonstration on Some Human Problems in High Performance Flight. Dr. G. Melvill Jones.

Thursday 14th January: LECTURE—The Future of Automatic Control on Fixed Wing Aircraft. Professor G. A. Whitfield.

Friday 15th January: AGRICULTURAL AVIATION GROUP—Biological Factors in Agricultural Aviation. C. V. Dadd.

Tuesday 19th January: LECTURE—Some Aerodynamic Problems of Engine Installation. Dr. J. Seddon.

Thursday 21st January: MAIN LECTURE AT CAMBRIDGE BRANCH—Research at the College of Aeronautics, Cranfield. Professor A. J. Murphy.

Friday 29th January: MAN POWERED AIRCRAFT GROUP—Engineering Problems in Man Powered Flight. B. S. Shenstone.

Tuesday 2nd February: LECTURE—Suppression of Shock-Induced Separations by Boundary Layer Control. H. H. Pearcey.

Friday 5th February: FIRST ROTORCRAFT SECTION LECTURE—Vertical Transport Business. R. L. Cummings, Jnr.

Tuesday 9th February: LECTURE—Model Testing in the Aircraft Research Association Co-operative Wind Tunnels. E. C. Carter.

Friday 12th February: AGRICULTURAL AVIATION GROUP—Choice of Aerial Vehicle. Peter King and D. F. Myres.

Wednesday 17th February: MAIN LECTURE AT BRISTOL BRANCH—Firestreak. G. H. F. Brown.

Thursday 18th February—ASTRONAUTICS AND GUIDED FLIGHT SECTION—Polar Missile Control Problems. D. Best.

Tuesday 23rd February: LECTURE—Relationship between Theory and Practice in Structural Problems. A. J. Troughton.

Friday 4th March: ROTORCRAFT SECTION LECTURE—British Research on the Aerodynamics of Powered Lift Systems. Dr. J. Williams.

Tuesday 8th March: LECTURE—Electronic Microcircuits. Dr. J. W. Granville.

Friday 11th March: All Day Discussion on Vehicle and Instrumentation Problems in Upper Atmosphere Research.

Tuesday 15th March: LECTURE—Some Problems of Separated and Vortex Flow. Professor H. B. Squire.

Thursday 17th March: MAIN LECTURE—Supersonic Aircraft—Promise and Problems. M. B. Morgan.

Friday 18th March: AGRICULTURAL AVIATION GROUP—Film Evening.

Thursday 24th March: MAIN LECTURE—Engines for Supersonic Air Liners. Dr. R. R. Jamison, and R. J. Lane.

Friday 25th March: MAN POWERED AIRCRAFT GROUP—Aerodynamics of Man Powered Flight, with special reference to Inflatable Wings. D. Perkins.

The following lectures will complete the Programme:—

Thursday 7th April: MAIN LECTURE AT THE COVENTRY BRANCH—The Optimum Size of Rocket Engines. J. E. P. Dunning.

Friday 8th April: ROTORCRAFT SECTION—Experiences with an Operational Heliport. R. A. C. Brie.

Friday 22nd April: AGRICULTURAL AVIATION GROUP—Pilot Training. Captain R. Bradbury and J. M. McMahon.

Friday 6th May—ROTORCRAFT SECTION—The Personal Helicopter. J. S. Shapiro.

Thursday 12th May: ASTRONAUTICS AND GUIDED FLIGHT SECTION—On Reducing Costs of Space Research. J. E. Allen.

Tuesday 17th May: HISTORICAL GROUP—Lecture by Sir Thomas Sopwith.

Thursday 19th May: 48TH WILBUR WRIGHT MEMORIAL LECTURE—Mathematics and Aeronautics. M. J. Lighthill.

Friday 10th June: ROTORCRAFT SECTION—Helicopter Vibration. Dr. J. P. Jones.

New By-Laws

The Privy Council have ratified the amendments in the Society's By-Laws which were passed at General Meetings of Members held on the 3rd December 1958 and the 4th May 1959. A full report of the Meeting held on the 3rd December 1958, was published in the January 1959 JOURNAL. The Resolution putting forward the new rates of subscriptions was adopted.

The Council wish to take this opportunity of thanking the By-Laws Sub-Committee under the Chairmanship of Mr. A. V. Cleaver, for their work which involved many meetings.

The majority of the revisions are made to give clarification to the previous By-Laws, but there are a number of new By-Laws, among them one on election to Fellowship. Particulars are given below. Another new By-Law to which members attention is drawn is the addition of the Chairmen of the Sections of the Society and of Presidents of the New Zealand, Australian and Southern Africa Divisions to serve as Members of Council *ex-officio*. By this means the Divisions will have full knowledge of the matters which the Council has under discussion.

The new By-Laws came into force on 11th January 1960, and will be reprinted and distributed to all members.

By-Law 2(D)

Fellowship

"Application for Fellowship must be proposed by a Fellow and supported by three other Fellows. Every Candidate for election into the class of Fellow shall be an Associate Fellow or possess the qualifications necessary for Associate Fellowship. Furthermore, in the opinion of the Council:—

(*a*) He shall have made outstanding contributions in the profession of aeronautics.

or

(*b*) He shall have attained a position of high responsibility in the profession of aeronautics

or

(*c*) He shall have had long experience of high quality in the profession of aeronautics."

Garden Party

The Council decided that in view of the many extra commitments being undertaken during the year, it would not be possible to hold a Garden Party in 1959. It has also been decided not to hold one in 1960.

Fifth Air Transport Course

The Fifth Air Transport Course was again held at Oriel College, Oxford from 20th March to 9th April 1960. Forty-four students enrolled for the Course, the highest number for any course so far. This means that nearly 200 Students will have attended the five Courses. This year, nearly half the Students came from overseas—from Canada, East Africa, Jugoslavia, Italy, Brazil, India, Portugal, Switzerland and Sweden.

The Lectures by the resident Lecturers have been supplemented by nineteen Guest Lecturers and seven Guest Evening Speakers.

Astronautics and Guided Flight Section

The Second Annual General Meeting of the Astronautics and Guided Flight Section was held on Wednesday 27th May 1959, at 5.30 p.m.

The Chairman, Sir George Gardner, announced the names of those elected to the Committee by ballot. These were:—Mr. A. D. Baxter, Mr. D. J. Farrar and Professor G. A. Whitfield.

At the first Meeting of the Committee, Mr. A. V. Cleaver was elected Chairman.

The Committee recommended lectures to the Council and and these have been included in the lectures previously listed. Once again, the lectures have been well attended and have again demonstrated the worth of the Section's activities.

The Council wish to thank Mr. A. V. Cleaver and his Committee for their efforts in furthering the objects of the Society in this field.

The Rotorcraft Section

The Rotorcraft Section of the Society formally came into existence on 8th January 1960, when the merger of the Helicopter Association of Great Britain with the Royal Aeronautical Society became effective.

The President and Council of the Society extend a warm welcome to the Helicopter Association and its members as the Rotorcraft Section of the Society and hope that this new Section will contribute as much to the science and operation of rotating wing aircraft as has the Helicopter Association.

The Executive Council of the Association has agreed to serve as the first Committee of the Rotorcraft Section. *See* Committees of Council, p. 250.

The "Journal of the Helicopter Association of Great Britain" ceased publication with the issue of Number 6, Volume 13 (December 1959); the lectures and activities of the Rotorcraft Section—like those of the Society's other Sections and Groups—will be published in the Society's JOURNAL.

Lectures arranged for the 1959/60 Session of the Helicopter Association are being given as lectures of the Rotorcraft Section.

Graduates' and Students' Section 1959-60

During the year, the Graduates' and Students' Committee organised eight lectures, seven visits, two film shows and two dances. It also kept under review a number of matters affecting the interests of Graduates and Students. The Members of the Section Committee are listed under Committees of Council, p. 250.

Lectures and Visits

The average attendance at lectures and film shows was 73, an increase of 24 on the figure for the previous year.

A highlight of the year's programme was a lecture on the U.S. aircraft industry by Mr. Donald Douglas, Jr., President of the Douglas Aircraft Company. (*See* August 1959 JOURNAL.)

A new feature of the visits programme was a weekend visit to the Paris Air Show in June. An aircraft was chartered and 36 members spent a weekend in Paris for only £10 10s. 0d. a head including travel and hotel accommodation.

Dances

The Section's two dances, on 12th June and 20th November 1959, were both successful; total attendance at the two was 284. The policy of standardising ticket charges at 7s. a head proved popular.

Other Activities

The Section's page in the JOURNAL gives news of future Section activities and publishes reports on lectures and visits. Other matters of interest to members are also covered. During the year these have included a report about prospects in the Industry for members who have just graduated.

Lecture Theatre

The Section donated twenty guineas to the Lecture Theatre.

Thanks

The Committee wishes to thank all those who have given lectures and arranged visits. It also wishes to thank the members of the Society's staff who have helped with the work of the Section.

Lectures and Film Shows

1959

23rd March—Escape from Military Jet Aircraft. Wing Cdr. J. Jewel.

8th April—The American Aircraft Industry. Donald W. Douglas, Jr.

23rd September—Film Show.

7th October—Lunar Probes. J. E. Allen.

28th October—The Setting of Aircraft Specifications. R. H. Whitby.

11th November—The Flight Testing of Rotorcraft. Sqn. Ldr. W. R. Gellatly.

2nd December—Aerodynamics of Racing Cars. F. A. Costin.

1960

13th January—Aviation Medicine in the Space Age. Wing Cdr. F. Latham.

27th January—Problems and Prospects in British Aviation. Peter G. Masefield.

24th February—Annual General Meeting and Film Show.

9th March—The Hovercraft and its Development. W. J. Eggington.

Visits

15th April 1959—Royal Aircraft Establishment, Bedford.

19th/21st June 1959—Paris Air Show.

16th September 1959—A. and A.E.E., Boscombe Down.

14th October 1959—London Airport.

21st November 1959—A.E.R.E., Harwell.

5th December 1959—College of Aeronautics, Cranfield.

24th February 1960—Ford Motor Co. Ltd., Dagenham.

Historical Group

The Council have approved the formation of an Historical Group within the Society, having received a request to do so from fifteen members. Approval was granted on 24th September 1959 and a Steering Committee was appointed under the Chairmanship of Colonel R. L. Preston. The aims and objects of the Group are "To study and to promote interest in the History of Aeronautics." The first act on the part of the Committee was to approve a preliminary Register of historic aircraft still in existence. The publication of the Register has resulted in more interesting information coming to light. The Group is now working on the preparation of a questionnaire to be sent to known collectors of historical material to find out how much material is available, where it may be found and whether it may be used by those undertaking historical research. It is hoped that through this questionnaire, a central registry may be built up and a properly co-ordinated index of historical data on the development of Aeronautics be compiled.

Historic Aircraft Maintenance Group

This Group, which was formed in July 1958 in association with the Society of Licensed Aircraft Engineers, is now working at London Airport on the Nash Collection of Veteran Aircraft. Thanks to the generosity of British European Airways, one of the bays in the new Vanguard hangar has been made available to the Society for temporary accommodation. The Council is grateful to the Hawker Aircraft Ltd., who have supplied all the materials required for the repair and overhaul of these aircraft, and to Shell-Mex and B.P. Ltd., Dunlop Rubber Co. Ltd. (Aviation Division) and C.I.B.A. (A.R.L.) Ltd., for the supply of essential materials. Acknowledgment was made to individuals and other organisations in the August JOURNAL.

Thanks to the initial help given by the Air Ministry by lending the Society a hangar at Hendon and, more recently, to B.E.A., the work on the Nash Collection to prepare them for public display is now proceeding in ideal surroundings. It is a matter for regret that there is still no permanent accommodation but the Council does not despair of finding them a proper home.

Man Powered Aircraft Group

The Inaugural Meeting of the Man Powered Aircraft Group was held on 30th October 1959, when the President of the Society was in the Chair.

The Group was formed in April 1959, and the Steering Committee is listed in the Committees of Council on p. 251.

Since its formation, the Group has held a number of lectures which have been incorporated in the programme of lectures given before the Society published with this Report.

In November 1959, the Group were greatly encouraged by the announcement that Mr. Henry Kremer had generously offered a prize of £5,000 for the first successful flight of a man powered aircraft, designed, built and flown within the British Commonwealth under conditions laid down by the Royal Aeronautical Society, in collaboration with the Royal Aero Club. The conditions of the award of the prize have now

been published and particulars can be obtained from the Secretary of the Society.

A number of donations have been received towards the activities of the Group and it is hoped particulars will be published later.

Agricultural Aviation Group

The formation of the third of the Society's Groups, the Agricultural Aviation Group, was approved by Council on 30th April 1959. Its aims are to further the use of aircraft in agriculture, forestry, pest control, fertilising, seeding, chemical application and similar subjects; and to provide facilities for those interested in such matters to meet and exchange ideas and information.

The present Chairman, Mr. S. W. G. Foster, A.F.R.Ae.S., was largely responsible for the Group's formation. The Steering Committee, which is managing the Group's affairs until elections take place at the Group's Annual General Meeting in May 1960, is listed with the Committees of Council on p. 251.

The Group took an active part in the International Agricultural Aviation Conference, held at Cranfield in September 1959, which the Society helped to organise.

The Group has arranged a number of lectures and a film evening; these are listed in the main Society programme on p. 234.

A full programme for lectures is being arranged, in consultation with the Lectures Committee, for the 1960/61 Session and future activities will include visits to research centres and operating companies. The Group is preparing a Bibliography on Agricultural Aviation to be kept in the Society's Library.

Divisions

Under the new By-Laws the President of each Division becomes, *ex-officio*, a member of the Council. It is not expected that the Presidents will find themselves able to attend the Meetings of the Council, but by receiving Agenda and Minutes of the Council Meetings they will be able to keep abreast of the current activities of the Society and make contributions by post, giving the opinions and advice of the Division.

During the year visitors from the Divisions have not been as numerous as in previous years, but the President and the Council were pleased to welcome Mr. K. A. Greager, Vice-President of the Southern Africa Division, to the Dinner after the Commonwealth Lecture.

The visit of Sir Roy Fedden to New Zealand aroused considerable interest and has resulted in the formation of the Fedden Committee to investigate the place of New Zealand in aviation. The New Zealand Division is active in raising the prestige of the Society in New Zealand and the acceptance of the A.F.R.Ae.S. by the Burnham Committee will be a matter of satisfaction to them also.

Branches

The number of the Branches in the United Kingdom remains at twenty-eight. Some of the Branches appear to be having a lean year, following the years of plenty but, in general, the activities are being maintained at the usual level.

The occasion of a Memorial Lecture—of which there are seven—has resulted in the presence of the President and some Members of the Council. The standard of the lectures has been high, and the attendances has been equally so.

This year the Spring Branches' Conference is to be held at Brough and the Secretaries of the Branches are looking forward to the second Conference held outside London.

Since January 1960 the Branches have had their own page in the JOURNAL.

Membership

The total membership of the Society at the end of 1959 was 10,723, an increase of 183 over the previous year. The general upward trend in most classes was maintained, although the number of new members was less than in 1958. In 1958 the flattening of the upward curve was mainly due to an increase in the number of resignations and terminations. This tendency was repeated in 1959 and the total losses for these causes were 447 compared with 272 in the previous year. The number of new members elected, 682, is encouraging, considering the present fluid state of the Aircraft Industry.

The number of new Associate Fellows was rather less than last year (168 as against 190) and new Associates dropped to 119 from 192. New Graduates rose from 135 to 144 and Companions from 15 to 20. New Students fell to 230 from 364.

The slight drop in new elections had been anticipated when the new subscriptions were proposed but it is rather less than had been expected. The effect of the new By-Laws with regard to Fellowship, the re-appraisal of the Associate Fellowship examination and of exemptions from it by the Education Committee, and the merger with the Helicopter Association of Great Britain will all have an effect upon the Society's future and will tend to strengthen it.

The table at the foot of the page shows the Membership Figures as at 31st December 1959.

Medals and Awards of the Society

Full particulars of the Medals and Awards of the Society were published in the June and July 1959 JOURNALS.

HONORARY FELLOWS

The Council has pleasure in recording that Honorary Fellowship, the highest honour the Society can confer, was awarded to the following:—

PROFESSOR J. ACKERET; SIR WILLIAM S. FARREN, C.B., M.B.E., M.A., D.Sc., F.R.S., F.R.Ae.S., M.I.Mech.E., Hon.F.I.A.S., MR. S. B. GATES, O.B.E., M.A., F.R.S., F.R.Ae.S.

HONORARY COMPANIONS

The Council has pleasure in recording that the following have been made Honorary Companions of the Society:—

MR. E. C. BOWYER, C.B.E.; SIR WILLIAM HILDRED, C.B., O.B.E., M.A.

ROYAL AERONAUTICAL SOCIETY PRIZES IN AERONAUTICS

The Society's Prizes in Aeronautics, awarded annually to the best student in the Aeronautical Department at Universities

MEMBERSHIP AT 31st DECEMBER 1959

Grade	London Register	Australian Division	Southern Africa Division	New Zealand Division	Life and Honorary	Totals	Suspended London Register Members (included in the foregoing figures)	1959 Elected Members not yet Paid (included in the foregoing figures)
Hon. Fellows	— (—)	— (—)	— (—)	— (—)	30 (H) (28)	30 (28)	— (—)	— (—)
Fellows	450 (444)	18 (16)	1 (2)	4 (4)	12 (H) (—) 18 (L) (18)	503 (484)	7 (4)	— (—)
Associate Fellows	4528 (4403)	193 (180)	67 (64)	43 (40)	21 (H) (—) 16 (L) (17)	4868 (4704)	179 (93)	6 (24)
Associates	2139 (2190)	87 (90)	107 (98)	60 (67)	1 (H) (—) 5 (L) (5)	2399 (2450)	168 (104)	14 (9)
Graduates	1195 (1145)	43 (41)	6 (4)	3 (2)	— (—)	1247 (1192)	64 (45)	17 (8)
Students	1366 (1362)	43 (46)	7 (9)	4 (4)	— (—)	1420 (1421)	150 (99)	24 (19)
Founder Members	— (9)	— (—)	— (—)	— (—)	10 (H) 1 (L)	10 (10)	— (—)	— (—)
Hon. Companions	— (—)	— (—)	— (—)	— (—)	8 (H) (6)	8 (6)	— (—)	— (—)
Companions	160 (170)	8 (8)	7 (6)	4 (3)	6 (L) (7)	185 (194)	8 (8)	3 (1)
Temp. Hon. Members	— (—)	— (—)	— (—)	— (—)	53 (H) (53)	53 (53)	— (—)	— (—)
TOTALS	9838 (9723)	392 (381)	195 (183)	118 (120)	135 (H) (87) 45 (L) (48)	10723 (10542)	576 (353)	64 (61)

Figures in brackets are corresponding figures at 31st December 1958.

and Colleges organising courses in aeronautics, have been awarded for 1959 as follows:—

Bristol University: J. W. Britton and D. R. Philpott.
Cambridge University: C. G. B. Mitchell, St. John's College.
Glasgow University: Kenneth M. Nicoll.
Imperial College, London: B. N. Tomlinson and M. Lacey.
Queen's University, Belfast: Kenneth J. Holden.
Northampton College of Advanced Technology, London: G. N. Sage.
Queen Mary College, London: G. J. Shorey.
Southampton University: R. D. Ford.

SCHOLARSHIPS

The Geoffrey de Havilland Memorial Scholarship: A. J. W. Smith. (Mr. Smith also held this Scholarship for the year 1958/59.)

The Charter Scholarship was not awarded for 1959.

HENLOW CADET PRIZE

The Henlow Cadet Prize for 1959 was awarded to Pilot Officer D. R. West. The Prize is three years' subscription as a Graduate of the Society, with entrance fee, and a book of the winner's choice.

THE ELLIOTT MEMORIAL PRIZE

The Elliott Memorial Prize presented to the Apprentices receiving the highest marks in the General Studies Examination at Halton R.A.F. Station was awarded to the following:—

Warrant Officer Apprentice R. B. Thomson; Leading Aircraft Apprentice K. A. Wright.

GRANTS FROM THE EDUCATION FUND

Grants in aid of further study and research in aeronautics were awarded to the following:—

J. E. Hackett; S. A. Qureshi and J. D. Watkins. (The Edward Busk Studentship in Aeronautics was not awarded this year.)

Honours Awarded to Members

Members of the Society have been honoured by Her Majesty the Queen during the year. These the Council have much pleasure in congratulating.

Other Honours have been conferred upon Members of the Society by learned Societies and other bodies; the Council also congratulates these Members.

BIRTHDAY HONOURS LIST 1959

C.B.
Rear Admiral A. J. Tyndale-Biscoe (*Fellow*).

O.B.E.
E. J. Dickie (*Associate*).
K. O. Grant (*Associate Fellow*).
H. B. Irving (*Fellow*).
W. J. A. Thorn (*Associate Fellow*).

M.B.E.
D. Cameron-Douglas (*Associate Fellow*).

NEW YEAR'S HONOURS LIST 1960

K.B.E.
Admiral Sir Matthew Slattery (*Fellow*).
Air Marshal H. D. Spreckley (*Fellow*).

C.B.
R. H. Weir (*Fellow*).

C.B.E.
Air Commodore C. A. Turner (*Associate Fellow*).

O.B.E.
Wing Cdr. R. Hill (*Associate Fellow*).
Wing Cdr. L. Kendrick (*Associate Fellow*).
A. Symon (*Associate Fellow*).
P. H. Watson (*Associate Fellow*).

M.B.E.
E. J. Brunckhurst (*Associate Fellow*).
H. Lloyd (*Associate Fellow*).
F. M. Reynolds (*Associate Fellow*).
Sqn. Ldr. B. Trodd (*Associate Fellow*).

OTHER HONOURS AWARDED TO MEMBERS

Foreign Honorary Fellowship of the Institute of the Aeronautical Sciences was awarded to Mr. E. T. Jones (*Fellow*).

H. O. Short (*Honorary Fellow*) was elected a Fellow of the Royal Society of Arts.

Air Commodore F. R. Banks (*Fellow*) was awarded the Insignia Award in Technology, Mechanical Industries, for work on Aero Engines Research and Development by the City and Guilds of London Institute.

Professor O. A. Saunders (*Fellow*) was awarded Honorary Fellowship of the City and Guilds of London Institute.

Dr. Barnes N. Wallis (*Fellow*) was awarded the Honorary Degree of Doctor of Science in Engineering of Bristol University.

Dr. G. V. Lachmann (*Fellow*) was awarded the Honorary Degree of Doctor of Engineering (Dr.-Ing.e.H), by the Technical University of Aachen.

Sir Arnold Hall (*Fellow*) Immediate Past President of the Society was awarded the *Ir A. G. von Baumhauer Medal* for the period 1954-1959. This is awarded periodically to the person who, in the opinion of the Council and advisers of the Royal Netherlands Aero Club, has made the most valuable contribution in either a scientific or practical sense to flight safety.

Sir George Edwards (*Fellow*) Past President of the Society was awarded the *Daniel Guggenheim Medal for* 1959 for a lifetime devoted to the design of military and commercial aircraft culminating in the successful introduction into world-wide commercial service of the first turbine-powered propeller-driven aircraft.

de Havilland Comet. *The Elmer A. Sperry Award for* 1959 was presented to the de Havilland Aircraft Co. Ltd., on the 7th October in New York during the Seventh Anglo-American Aeronautical Conference. The award is made annually for a distinguished contribution which through application, proved in actual service, has advanced the art of transportation, whether by land, sea or air. de Havilland have successfully developed the world's first jet-powered air liner, the de Havilland Comet.

Specially named in the citation are Sir Geoffrey de Havilland (*Honorary Fellow*), Mr. Charles C. Walker (*Honorary Fellow*), and the late Major Frank B. Halford.

Mr. W. Tye (*Fellow*) was awarded the *Flight Safety Foundation Aviation Week Award for* 1959 for distinguished service in achieving safer utilisation of aircraft.

Wladamir A. Reichel (*Associate Fellow*) was awarded the top honour of the *Department of Defense Medal* for exceptional meritorious service to the Department of Defense in the field of aircraft instruments.

Mr. J. Martin (*Fellow*) was awarded the *Cumberbatch Trophy for Air Safety* by the Guild of Air Pilots and Air Navigators. Mr. Martin is the designer of the Martin-Baker ejection seat.

Technical Department

The most significant feature of the operations of the Technical Department during the year was the increase in the demand for the informaion which it produces. This demand, which is reflected particularly by the number of complete sets of Data Sheets issued to new users, has been increasing steadily since 1955. In 1959, more complete sets of Data Sheets were issued than at any time since the war. Although records are not sufficiently complete, it is probable that more complete sets were issued than in any year since the technical work was started some twenty years ago. The significance of this new interest is revealed by the types of organisation which are making requests for the work to be issued to them. In broad terms, the interest in the newer items (such as the Fatigue Data Sheets) originates mainly in the Aircraft Industry and various aeronautical organisations, while a large part of the new interest in the longer established work on Structures and Aerodynamics occurs in organisations of wider scope which are beginning to utilise techniques originally developed for strictly aeronautical purposes. In addition to this new interest, it is clear that the large number of organisations already familar with the work are continuing to find it useful and to welcome the new information which is added at regular intervals.

New and revised data were added during 1959 to the Data Sheets on Aerodynamics, Performance and Fatigue and to the Material Properties Handbook, Volume I—Aluminium Alloys which is produced in co-operation with NATO/AGARD.

Six subjects were included in the ten new Aerodynamics Data Sheets issued during the year:—normal forces and centres of pressure of conical frustum boat tails at supersonic speeds; normal forces on isolated bodies at large incidences and supersonic speeds; centres of pressure of isolated bodies at small and large incidences at supersonic speeds; ground effect on lift and drag; lift curve slopes of wing body combinations at transonic and supersonic speeds and flow field of a subsonic axisymmetric jet in a parallel stream. The pertinence of these subjects to the present day needs of the profession are too obvious to require comment here; what is not quite so obvious is the extent to which the Data Sheets which are produced crystallise reliable information. As an example of this, after considering all the information available, the results of 35 published and unpublished reports originating in four countries were utilised in

producing one Data Sheet on ground effect. Work on real gas effects, transonic and supersonic area rule and optimum body shapes, split flaps on thin swept-back wings, supersonic stability derivatives and internal aerodynamics is currently progressing.

Perhaps of greatest interest among the eight new Fatigue Data Sheets issued during the year is a series on statistics. It was found that there was a certain amount of inconsistency between various standard texts on this subject and, further, that the presentation of the subject made by statisticians was not particularly suited to the engineering application. With the assistance of statisticians and a number of engineers who had experience in the use of statistics a series of Data Sheets was evolved explaining in consistent and straight-forward terms the philosophy of the subject, the terms and procedures used and presenting the numerical data necessary for carrying out some of the more standard processes having particular application to the fatigue problem. This series has been particularly well received as it forms a compact source of reference for engineers who might otherwise avoid the use of many statistical processes which can be of assistance to them. Also included in the supplementary issue were data on axial loading machines, stress concentration, stresses due to interference fit pins and the effect of interference fit pins on fatigue life. The last mentioned was the subject of a tentative Data Sheet. The issue of such a sheet is a new departure; while the data which it contains is thoroughly substantiated there is insufficient information available to confirm all the inferences which may be drawn by using the sheet. The limitations are clearly stated and the sheet is printed in red to draw attention to its special nature. It was considered that the issue of this information provided valuable data which could not otherwise be obtained and that its use would provide a feedback of further information on which a better quantitative understanding of interference fit pins could be based. Work is at an advanced stage on further fatigue Data Sheets covering bolts, riveted points and lugs.

An issue of six Performance Data Sheets marked the complete re-establishment of the Society's work on this subject; this was the first supplementary issue to be made since 1953. The topics covered the correction to indicated Mach number for static pressure errors; optimum climb techniques for minimum time or fuel to a given height and speed, for minimum time or fuel to a given height, speed and distance and for minimum stage time or fuel, estimation of turning performance and estimation of rolling manoeuvrability. These first results of the re-establishment of the work have induced new interest in this side of the Society's technical activities and resulted in a sizable increase in the number of up-to-date Performance volumes in use. At the present time, work is proceeding on the correction of flight instruments, estimation of landing performance, tyre-runway coefficients of friction and the review of some of the older work contained in the series.

There was no issue of new work during 1959 on Structures although a number of Data Sheets were completed ready for issue in 1960. This issue will contain sheets or series of sheets on the local failure of struts, the deformation of flexible circular frames, the wrinkling of sandwich panel face plates and the modulus of rigidity of orthotropic sandwich cores. One of the larger investigations conducted concerned the buckling and failure of shear webs with flanged and unflanged lightening holes. The future programme of the Committee is at present under review to establish the priorities of new work on Structures.

A first issue of 85 pages of amendments and additions to the Material Properties Handbook—Volume I, Aluminium Alloys, was made towards the end of 1959. In addition to revising and adding new data to the existing sections, completely new sections covering alloys produced in Belgium, Germany and the Netherlands were included. Most of the collection and correlation of the data for Volume II—Steels, was completed and it is anticipated that this will be issued very shortly. It will be of approximately the same size as the original issue of Volume I and contain physical and mechanical properties of three categories of aircraft steels at room and elevated temperatures. The three categories relate to the temperature range of prime usefulness of the steels, *i.e.* room temperature, room temperature up to 1100°F and above 1100°F. This work is undertaken in co-operation with NATO's Advisory Group for Aeronautical Research and Development.

The work of the staff has been continuously monitored and guided by the Society's Technical Committees and many members of these Committees have undertaken specific projects to aid the work or have arranged for experimental and computational programmes to provide additional data. These committees are at present constituted as follows (the year of original foundation is given in brackets):—

Aerodynamics Committee (1942)

Prof. A. D. Young (*Chairman*)	J. W. Fozard	J. D. Poole
	Dr. D. W. Holder	R. A. Shaw
J. R. Collingbourne	R. Melling	H. H. B. M. Thomas
R. Dickson	H. Metcalfe	A. K. Weaver

Fatigue Committee (1955)

H. L. Cox (*Chairman*)	A. J. Fenner	N. H. Mason
R. J. Atkinson	Dr. G. Forrest	R. H. Sandifer
K. E. Cheverton	H. B. Howard	J. K. Williams

Performance Committee (1946)

R. H. Whitby (*Chairman*)	J. R. Collingbourne	J. C. Stevenson
	R. P. Dickinson	C. F. Toms
D. G. Brown	G. E. Rogerson	A. H. Yates

Structures Committee (1940)

H. B. Howard (*Chairman*)	Prof. W. S. Hemp	E. Loveless
	D. James	Dr. E. H. Mansfield
H. L. Cox	E. D. Keen	F. Tyson

Members of the Technical Department have continued to assist in the organisation of many of the Society's activities. The largest commitments of this type during the year were in connection with the organisation of the Seventh Anglo-American Conference, the All-Day Discussions on the Effects of Kinetic Heating, Flight Safety and Vehicle and Instrumentation Problems in Upper Atmosphere Research. Members of the Technical Staff have represented the Society on various other bodies and continued to provide technical assistance to members and others on a wide range of problems.

The Library

In 1950, the Library made 632 loans. The figure for 1959 is 1,570. The difference can be accounted for in several ways, notably the increased acquisition of American preprints and a constant endeavour to meet requests with the utmost despatch.

The year has seen a greater interchange with aircraft firms' Libraries, but this "interchange" is almost wholly one way. The Society's Library has an increasing reputation for holding the "difficult" items and this is largely due to happy relations with many organisations in the United States. The Society of Automotive Engineers, for instance, donates all its aeronautical preprints to the Society.

Library acquisitions showed a drop from 309 in 1958 to 297. Review copies totalled 157, again a lower figure than the previous year but thrice the number for 1950. Ten more reports than in 1958 were received—a total of 723.

The changing scene is reflected in an increase in books, periodicals and reports on electronics, astronautics and missiles. All these increases require space and it is hoped that the new building will do something to alleviate the present considerable over-crowding and consequent difficulty of access in the Library.

Almost coincident with the formation of the Society's Historical Group was the presentation, by Mrs. Claude Grahame-White, of her husband's large collection of photographs, chiefly illustrative of the years when he was establishing a reputation as a pioneer and as a record-breaker. Various other interesting and valuable historical presentations have been made during the year, each of which has been recorded in the JOURNAL and it is hoped that the foundation of the Historical Group will underline the Society's interest in this side of aeronautics with a consequent fillip to the presentation of other historical items.

The foundation of the Man Powered Aircraft Group too, was reflected in an increased interest in literature on the subject. This interest extended to technical inquiries on aerofoils—a type of inquiry that could not, normally, be answered by a library but thanks to the co-operation of the Society's Technical Department, even these inquiries could be dealt with. Members may not appreciate that the presence, within the Society, of a technical department, gives much greater scope to the service that the Library is able to give and the fact that these esoteric questions do not have to be "farmed out" by post gives a service that is speedier than would otherwise be possible.

The Society subscribes to the library inter-loan services of both the National Central Library and the Association of Special Libraries and Information Bureaux (ASLIB), of both of which the Society is among the oldest members. It is gratifying to note that while both these bodies use the Society to a considerable extent, the Society rarely has reason to call on them.

There can be no doubt that the Society's reputation as a source of information increases yearly which, while gratifying, inevitably means an increase of calls on its services.

Publications

The dispute in the Printing Industry, with the prospect of increased costs, and the uncertainty about the advertisement revenue, have made the past year a difficult one for the JOURNAL. Fortunately, the increased costs have not been as great as had been expected and they did not take effect until November. Considering the present circumstances the advertising managers have done well in their first year; consequently the overall results have been better than had been anticipated.

Because of the printing dispute different and faster methods of binding the July and August JOURNALS were adopted and they were distributed together but, the JOURNAL was exceptionally fortunate in not having to miss an issue.

In November because of the rebuilding at 4 Hamilton Place, the Editorial Offices were moved to the Society's premises at 8 Hamilton Place. This contributed to the delay in the production of the December JOURNAL and, inevitably the January and February JOURNALS were also late. The schedule is being restored and by May the JOURNAL should be back to its usual distribution date between the 1st and 10th of the month.

Under the new policy for lectures adopted by the Council at the beginning of the 1959-60 session, publication in the JOURNAL is assured to only the Louis Blériot Lecture, Lanchester and Wilbur Wright Memorial Lectures and the British Commonwealth Lecture. Publication of other lectures will be on the recommendation of referees and some of the more specialist lectures may be published in THE AERONAUTICAL QUARTERLY. Summaries of all lectures are now published in the Notices Section of the JOURNAL.

For the first time a few special positions for advertisement pages are being permitted in the JOURNAL, from January 1960. These pages will be restricted in number and will only appear immediately preceding or following the papers of either of the Sections, *i.e.* Astronautics or Rotorcraft or, where applicable, the papers of any of the Groups.

During the past year the Journal and Publications Committee has continued to discuss the proposal to publish a comprehensive Subject-Author Index for all the Society's publications to be completed in 1966. This will obviously be a difficult task involving much work and expense and the final details have yet to be settled.

Publication of a List of Members has been recommended and it is hoped that it will be issued before the end of 1960.

THE AERONAUTICAL QUARTERLY has had a successful year and a marked increase in circulation is recorded. Research papers of a high standard, maintained by the invaluable work of the Editorial Board and the Editorial Referees, are now published quickly; good short papers are published very quickly. The Editor of THE AERONAUTICAL QUARTERLY is always pleased to discuss with authors the publication of current and future research work of a specialised nature, in aeronautics and in the allied sciences.

The Council is grateful to the many members of the Society, and to those non-members (in Industry, the Research Establishments and the Universities), who give valuable assistance in refereeing papers for both the JOURNAL and THE AERONAUTICAL QUARTERLY.

As always, the co-operation shown and the service given by the Society's printers has been of the highest order.

The Anniversary Luncheon

The 94th Anniversary of the Society was celebrated by a Lunch at the Dorchester, Park Lane, on 12th January 1960, when the Minister of Aviation, The Right Hon. Duncan Sandys, was the Guest of Honour. There were over 400 members and guests present at the lunch, including some of the oldest members of the Society and many pioneers in the World of Aviation.

A full report was published in the March 1960 JOURNAL.

Dinner to Past Presidents of the Society

Mr. Peter G. Masefield, President of the Society, gathered together the Past Presidents of the Society for a reunion dinner and the following Past Presidents were able to be present:

1950-51 Major G. P. Bulman	1938, 1939, 1945 Sir Roy Fedden
1951-52 Sir John S. Buchanan	1942-44 Sir Arthur Gouge
1954-55 Sir Sydney Camm	1958-59 Sir Arnold Hall
1947-49 Sir Harold Roxbee Cox	1956-57 Mr. E. T. Jones
1957-58 Sir George Edwards	1945-47 Sir Frederick Handley Page
1953-54 Sir William Farren	1955-56 Mr. N. E. Rowe

Dr. A. M. Ballantyne and Captain J. Laurence Pritchard were also present. Mr. Alec Ogilvie, Mr. H. E. Wimperis, Lord Brabazon, Lord Sempill and Sir George Dowty were unable to be present.

A copy of the Menu was autographed by all those present and has been placed in the archives of the Society with many items of a similar nature now in the Society's records.

Dinner to the Minister of Aviation

The President and Council entertained to dinner the Minister of Aviation, The Right Hon. Duncan Sandys, in the Offices of the Society on 18th February 1960. In addition to the Council there were present a number of officials of other bodies and other guests. The Minister was thus given an opportunity to meet them in an informal atmosphere.

7th Anglo-American Aeronautical Conference, New York, 1959

The Seventh Anglo-American Aeronautical Conference was held in New York from 4th to 16th October 1959. An interesting and informative programme was arranged by the American hosts and the Council would like to thank them once again for their great hospitality.

A full Report was published in the January 1960 JOURNAL.

A start has already been made on arrangements for the Eighth Conference to be held in the United Kingdom.

Second International Congress of the Aeronautical Sciences

The Second International Congress of the Aeronautical Sciences will be held in Zurich, Switzerland, from 12th September to 16th September 1960. The first Congress was held in Madrid in September 1958, when more than sixty Members of the Society attended. It is hoped that many members of the Society will attend the Second Congress which has every appearance of being as interesting as the first.

Ties for Members

In response to many requests from Members, a tie has been specially designed for the Society and is now available. The tie for Members of the Society consists of gold falcons, with wings outstretched (as on the Society's badge), on a navy blue background. They are silk, cost one guinea, and are obtainable only from Rowans Ltd., Buchanan Street, Glasgow.

A tie for Branch Members, which has gold falcons on a maroon background, is available from the Secretaries of the Branches, at one guinea.

Associate Fellowship Examinations, 1959

The Associate Fellowship Examinations were held in June and December 1959, at home and overseas. The Council wish to record their thanks for the help given by the Examiners and to those who organised the arrangements for the overseas candidates. Thirty-five candidates took Part I of the examination and thirty took Part II. The Examination was held at the following overseas centres:—

Bangalore, Bombay, Delhi, Kanpur, Madras, Poona, Calcutta and Hyderabad, New York, Vancouver, Southern Rhodesia and New Zealand.

The Burnham Committee

In February 1960, the Council announced that the Burnham Committee had decided to accept the Associate Fellowship of the Society for the purposes of the graduate addition, subject to certain provisos. The following is the letter received from the Honorary Secretary of the Committee:—

10 Queen Anne Street, W.1.
22nd January 1960.

". . . . I am happy to be able to advise you that a decision has now been made accepting the Associate Fellowship of the Royal Aeronautical Society for the purposes of the graduate addition, provided that the teacher has obtained the qualification by examination and either

(*a*) Has passed one paper each from the following groups in Parts I and II of the Society's examination for Associate Fellowship
  (*i*) Advanced aerodynamics.
  (*ii*) Theory of structures.
  (*iii*) Aircraft design and development
  or examinations accepted by the Council as exempting the candidate from Parts I and II of the examination for Associate Fellowship, or

(*b*) Holds a Higher National Certificate or Higher National Diploma in Mechanical Engineering.

(*Signed*) W. P. ALEXANDER,
Hon. Secretary."

THE ROYAL

(INCORPORATED

BALANCE SHEET

1958 Figures £		£ s. d.	£ s. d.	£ s. d.
	CURRENT LIABILITIES			
9867	Sundry Creditors		11666 13 7	
5818	Subscriptions and other amounts received in advance		7813 8 10	
				19480 2 5
	AERONAUTICAL TRUSTS LIMITED			
—	Amount owing on Current Account			738 0 5
	SURPLUS (subject to depreciation of Investments)			
	Reserve for Conferences and Courses			
	Balance at 31st December 1958		3937 17 2	
	Add transfer from Income and Expenditure Account		2500 0 0	
			6437 17 2	
	Less Expenditure less receipts during year		2381 11 2	
3938			4056 6 0	
	Income and Expenditure Account			
	Balance at 31st December 1958	12212 10 2		
	Add Surplus of Income over Expenditure for year to date	2111 15 0		
			14324 5 2	
12213				18380 11 2
£31836				£38598 14 0

P. G. MASEFIELD
President.

G. P. BULMAN
Honorary Treasurer.

REPORT OF THE AUDITORS TO THE MEMBERS

In our opinion the above balance sheet and the annexed income and Society Endowment Fund included in the annexed accounts of Aeronautical Trusts Ltd., and of its surplus for the year ended on that date.

We have obtained all the information and explanations which we considered in agreement with them and the said information and explanations.

3 Frederick's Place, Old Jewry, London, E.C.2.
18*th March* 1960

AERONAUTICAL SOCIETY

BY ROYAL CHARTER 1949)

31st DECEMBER 1959

1958 Figures £		£ s. d.	£ s. d.
	CURRENT ASSETS		
1	Stock of Journals and other publications	1 0 0	
13461	Sundry debtors and payments in advance	12995 18 6	
6509	Balances at Bank and Cash in Hand	14595 14 6	
			27592 13 0
5600	**INVESTMENTS AT COST**		5600 0 0
	Market value 31st December 1959 £4,590 (1958 £4,474)		
	AERONAUTICAL TRUSTS LIMITED		
1	21 shares of 1/- each fully paid at cost	1 1 0	
859	*Amounts due on Current Account*	— — —	
			1 1 0
	PRINTED BOOKS, BINDINGS, OLD PRINTS, ETC.		
50	At nominal amount		50 0 0
	COLLECTION OF HISTORICAL AIRCRAFT (including Nash Collection)		
5355	At cost		5355 0 0
£31836			£38598 14 0

OF THE ROYAL AERONAUTICAL SOCIETY

expenditure account of the Society, together with the accounts of the Royal Aeronautical give a true and fair view of the state of the Society's affairs as at 31st December 1959,

necessary. In our opinion the Society has kept proper books, and the said accounts are

(*Signed*) PRICE WATERHOUSE & CO.

THE ROYAL

INCOME AND EXPENDITURE ACCOUNT

1958 Figures £			£ s. d.	£ s. d.
		ESTABLISHMENT EXPENSES		
	2864	Ground Rent, Heating, Lighting, Insurance and Repairs		2904 5 4
		ADMINISTRATIVE AND OFFICE EXPENSES		
15323		Salaries, Wages and National Insurance	14758 15 7	
2141		Pension and Pension Premiums	2609 10 8	
2251		Printing and Stationery	2864 7 11	
2519		Postages and Telephone	3114 12 5	
286		Travelling	261 9 0	
780		Office Furniture and Equipment	192 12 4	
760		Other Charges	959 14 2	
	24060			24761 2 1
		JOURNAL AND PUBLICATIONS		
4725		Salaries and Pension Premiums	4912 3 0	
22293		Printing	20194 0 10	
350		Printing Year Book	350 0 0	
4247		Postages and Wrappers	3830 19 0	
1607		Other Expenses	1687 19 7	
	33222			30975 2 5
		TECHNICAL COMMITTEES		
7682		Salaries and Pension Premiums	8605 15 2	
4945		Printing and other charges	3445 2 5	
307		Travelling Expenses	40 1 0	
	12934			12090 18 7
	2403	*Garden Party*		— — —
	802	EXAMINATIONS EXPENSES		793 15 2
	1740	MEETINGS AND LECTURES		1197 7 6
	1000	RESERVE FOR CONFERENCES AND COURSES		2500 0 0
	740	DINNERS AND RECEPTIONS		738 17 5
	25	SECTIONS AND GROUPS		206 11 11
		LIBRARY		
1702		Salaries and Pension Premiums	1704 0 0	
522		Expenses	653 14 3	
	2224			2357 14 3
	71	NASH COLLECTION MAINTENANCE EXPENSES		117 2 1
	665	BRANCHES SUBSIDIES		780 0 0
	220	PRIZES AND AWARDS		229 14 6
	300	CHARTER SCHOLARSHIPS		300 0 0
	504	LEGAL AND PROFESSIONAL CHARGES		578 16 0
	—	Balance being Surplus of Income over Expenditure for Year carried to Balance Sheet		2111 15 0
	£83774			£82643 2 3

AERONAUTICAL SOCIETY

FOR THE YEAR ENDED 31st DECEMBER 1959

1958 Figures			£ s. d.	£ s. d.
	£			
31489		MEMBERS' SUBSCRIPTIONS		44090 18 2
10511		DONATIONS AND GRANTS		11210 17 7
		INTEREST AND DIVIDENDS		
168		Interest on Investments (Gross)	168 0 0	
237		Interest on Deposit Account at Bank	232 11 10	
5773		*Surplus on Endowment Fund Income and Expenditure Account*	— — —	
———	*6178*			400 11 10
		JOURNAL AND PUBLICATIONS		
11278		Advertising Revenue	9987 2 3	
11309		Sales	11038 15 7	
———	*22587*			21025 17 10
		TECHNICAL COMMITTEES		
4750		Sales		5381 12 8
1727		*Garden Party*		— — —
464		EXAMINATIONS FEES		533 4 2
6068		*Excess of Expenditure over Income for Year*		— — —
£83774				£82643 2 3

AERONAUTICAL

BALANCE SHEET

1958 Figures £		£ s. d.	£ s. d.	£ s. d.
	SHARE CAPITAL			
	AUTHORISED: 40 shares of 1s. each		2 0 0	
1	ISSUED: 21 shares of 1s. each fully paid			1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND			
	CAPITAL ACCOUNT			
137820	Balance as at 31st December 1958		139021 9 8	
1174	*Add* Entrance Fees received during year		1965 15 0	
27	Donations received during year		5 5 0	
—	Contributions to Lecture Theatre Appeal		16786 19 2	
139021			157779 8 10	
	INCOME ACCOUNT			
9104	Balance as at 31st December 1958	9103 14 6		
	Add Surplus of Income over Expenditure for year to date	5534 3 4	14637 17 10	
148125				172417 6 8
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND			
	INCOME ACCOUNT			
523	Balance as at 31st December 1958		728 15 1	
205	*Add* Surplus of Income over Expenditure for year to date		365 11 10	
728				1094 6 11
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS			
	CAPITAL ACCOUNT			
5424	Balance as at 31st December 1958		5423 10 4	
—	*Less* Loss on Realisation of Investment		7 10 7	
5424				5415 19 9
	GEOFFREY DE HAVILLAND MEMORIAL FUND			
	CAPITAL ACCOUNT			
4216	Balance as at 31st December 1958		4236 17 5	
21	*Add* Donation received during year		22 0 0	
4237				4258 17 5
	WILBUR WRIGHT MEMORIAL FUND			
	CAPITAL ACCOUNT			
2212	As at 31st December 1958		2211 17 11	
	INCOME ACCOUNT			
136	Balance at 31st December 1958	116 17 6		
(—19)	*Add* Surplus of Income over Expenditure for year to date	15 8		
2329			117 13 2	
				2329 11 1
£160844	*Forward*			£185517 2 10

TRUSTS LIMITED

31st DECEMBER 1959

1958 Figures £		£ s. d.	£ s. d.	£ s. d.
1	CASH IN HAND			1 1 0
	ROYAL AERONAUTICAL SOCIETY ENDOWMENT FUND			
	Leasehold Property at cost *less* amounts written off 4, 8 and 9 Hamilton Place			
	At Cost	14185 1 9		
—	Additions at cost	4756 7 7		
		18941 9 4		
	Less Amortisation written off to date	11711 1 9		
3129			7230 7 7	
	Furniture at cost *less* depreciation			
	At cost	6396 1 11		
	Less Depreciation written off to date	5085 9 5		
1532			1310 12 6	
143723	Investments at cost		146244 16 11	
	Market value 31st December 1959 £146,074 (1958 £122,741)			
	Current Assets			
(—*859*)	Amount due from the Royal Aeronautical Society		738 0 5	
375	Sundry Debtors		1250 0 0	
225	Balance at Bank		15643 9 3	
148125				172417 6 8
	ROYAL AERONAUTICAL SOCIETY EDUCATION FUND			
602	Investment at cost		852 5 11	
	Market value 31st December 1959 £899 (1958 £630)			
126	Balance at bank		242 11 0	
			1094 16 11	
—	*Less* Amount due to Edward Busk Studentship Fund		10 0	
728				1094 6 11
	EDWARD BUSK STUDENTSHIP IN AERONAUTICS			
4807	Investments at valuation 31st December 1951		4181 10 0	
601	Investments at cost		1226 6 6	
	Market value 31st December 1959 £4,811 (1958 £4,655)			
			5407 16 6	
16	Balance at bank		7 13 3	
—	Amount due from the Royal Aeronautical Society Education Fund ...		10 0	
5424				5415 19 9
	GEOFFREY DE HAVILLAND MEMORIAL FUND			
4226	Investment at cost		4226 2 2	
	Market value 31st December 1959 £3,183 (1958 £3,083)			
11	Balance at bank		32 15 3	
4237				4258 17 5
	WILBUR WRIGHT MEMORIAL FUND			
2287	Investments at cost		2286 11 3	
	Market value 31st December 1959 £2,126 (1958 £1,797)			
42	Balance at Bank		42 19 10	
2329				2329 11 1
£160844	*Forward*			£185517 2 10

BALANCE SHEET—*Continued*

1958 Figures £		£ s. d.	£ s. d.	£ s. d.
160844	*Forward*			185517 2 10
	EDWARD BUSK MEMORIAL FUND			
	CAPITAL ACCOUNT			
1449	As at 31st December 1958		1449 6 1	
	INCOME ACCOUNT			
257	Balance at 31st December 1958	260 7 3		
4	*Add* Surplus of Income over Expenditure for year to date	1 4 4		
1710			261 11 7	
				1710 17 8
	PILCHER MEMORIAL FUND			
	CAPITAL ACCOUNT			
100	As at 31st December 1958		99 14 0	
	INCOME ACCOUNT			
81	Balance at 31st December 1958	85 18 0		
5	*Add* Surplus of Income over Expenditure for year to date	12 4		
186			86 10 4	
				186 4 4
	USBORNE MEMORIAL FUND			
	CAPITAL ACCOUNT			
109	As at 31st December 1958		109 2 5	
	INCOME ACCOUNT			
72	Balance at 31st December 1958	67 1 8		
(—5)	*Add* Surplus of Income over Expenditure for year to date	9 4		
176			67 11 0	
				176 13 5
	HERBERT ACKROYD STUART FUND			
	CAPITAL ACCOUNT			
691	As at 31st December 1958		691 9 0	
	INCOME ACCOUNT			
751	Balance at 31st December 1958	774 18 4		
24	*Add* Surplus of Income over Expenditure for year to date	31 12 4		
1466			806 10 8	
				1497 19 8
	R.38 MEMORIAL FUND			
	CAPITAL ACCOUNT			
982	As at 31st December 1958		981 13 10	
	INCOME ACCOUNT			
1287	Balance at 31st December 1958	1356 5 9		
69	*Add* Surplus of Income over Expenditure for year to date	34 17 4		
2338			1391 3 1	
				2372 16 11
	SIMMS GOLD MEDAL FUND			
	CAPITAL ACCOUNT			
528	As at 31st December 1958		527 15 9	
	INCOME ACCOUNT			
135	Balance at 31st December 1958	134 3 7		
(—1)	*Add* Surplus of Income over Expenditure for year to date	2 18 0		
662			137 1 7	
				664 17 4
	ALSTON MEMORIAL FUND			
	CAPITAL ACCOUNT			
250	As at 31st December 1958		250 8 10	
	INCOME ACCOUNT			
87	Balance at 31st December 1958	71 5 7		
(—16)	*Add* Surplus of Income over Expenditure for year to date	9 17 0		
321			81 2 7	
				331 11 5
£167703				£192458 3 7

REPORT OF THE AUDITORS TO THE

In our opinion the foregoing accounts give a true and fair view of the state of the surplus of the Funds for the year ended on that date.

We have obtained all the information and explanations which we considered necessary. agreement with them and with the said information and explanations, give in the prescribed

3 Frederick's Place, Old Jewry, London, E.C.2.

18*th March* 1960.

TRUSTS LIMITED

31st DECEMBER 1959

1958 Figures £		£ s. d.	£ s. d.	£ s. d.
160844	*Forward*			185517 2 10
	EDWARD BUSK MEMORIAL FUND			
690	Investments at cost		1705 10 5	
	Market value 31st December 1959 £1,559 (1958 £525)			
1020	Balance at Bank		5 7 3	
1710				1710 17 8
	PILCHER MEMORIAL FUND			
171	Investments at cost		170 13 8	
	Market value 31st December 1959 £115 (1958 £116)			
15	Balance at Bank		15 10 8	
186				186 4 4
	USBORNE MEMORIAL FUND			
174	Investments at cost		174 11 1	
	Market value 31st December 1959 £112 (1958 £114)			
2	Balance at Bank		2 2 4	
176				176 13 5
	HERBERT ACKROYD STUART FUND			
1428	Investments at cost		1428 5 10	
	Market value 31st December 1959 £1,012 (1958 £1,018)			
38	Balance at Bank		69 13 10	
1466				1497 19 8
	R.38 MEMORIAL FUND			
2303	Investments at cost		2302 17 3	
	Market value 31st December 1959 £1,627 (1958 £1,638)			
35	Balance at Bank		69 19 8	
2338				2372 16 11
	SIMMS GOLD MEDAL FUND			
649	Investments at cost		648 10 1	
	Market value 31st December 1959 £497 (1958 £492)			
13	Balance at Bank		16 7 3	
662				664 17 4
	ALSTON MEMORIAL FUND			
316	Investments at cost		316 7 6	
	Market value 31st December 1959 £229 (1958 £232)			
5	Balance at Bank		15 3 11	
321				331 11 5
£167703				£192458 3 7

MEMBERS OF AERONAUTICAL TRUSTS LTD.

Company's affairs and of the Funds administered by it as at 31st December 1959, and of the

In our opinion the Company has kept proper books, and the said accounts, which are in manner the information required by the Companies Act, 1948.

(*Signed*) PRICE WATERHOUSE & CO.

AERONAUTICAL
INCOME AND EXPENDITURE ACCOUNTS

1958 Figures £		£ s. d.
	ROYAL AERONAUTICAL SOCIETY	
655	Amortisation of Leasehold Property	655 0 0
320	Depreciation of Furniture	221 11 9
10	Legal Expenses	10 10 0
—	Lecture Theatre Appeal Expenses	1356 15 9
5773	Surplus of Income over Expenditure for the year carried to Balance Sheet	5534 3 4
£6758		£7778 0 10
	ROYAL AERONAUTICAL SOCIETY	
457	Grants made in 1959	325 0 0
205	Surplus of Income over Expenditure for the year carried to Balance Sheet	365 11 10
£662		£690 11 10
	EDWARD BUSK STUDENTSHIP	
£225	Transfer to Royal Aeronautical Society Education Fund	£230 14 8
	GEOFFREY DE HAVILLAND	
£121	Transfer to Royal Aeronautical Society Education Fund	£123 18 8
	WILBUR WRIGHT	
100	1959 Lecture Premium	100 0 0
—	Surplus of Income over Expenditure for the year carried to Balance Sheet	15 8
£100		£100 15 8
	EDWARD BUSK	
21	1959 Award	21 0 0
—	Contribution to Wilbur Wright Memorial Fund	18 0 0
—	Contribution to Pilcher Memorial Fund	5 0 0
—	Contribution to Usborne Memorial Fund	5 0 0
4	Surplus of Income over Expenditure for the year carried to Balance Sheet	1 4 4
£25		£50 4 4
	PILCHER	
—	1959 Award	10 10 0
5	Surplus of Income over Expenditure for the year carried to Balance Sheet	12 4
£5		£11 2 4
	USBORNE	
10	1959 Award	10 10 0
—	Surplus of Income over Expenditure for the year carried to Balance Sheet	9 4
£10		£10 19 4
	HERBERT ACKROYD	
21	1959 Award	21 0 0
24	Surplus of Income over Expenditure for the year carried to Balance Sheet	31 12 4
£45		£52 12 4
	R.38	
—	1959 Award	50 0 0
70	Surplus of Income over Expenditure for the year carried to Balance Sheet	34 17 4
£70		£84 17 4
	SIMMS GOLD	
20	1959 Award	20 0 0
—	Surplus of Income over Expenditure for the year carried to Balance Sheet	2 18 0
£20		£22 18 0
	ALSTON	
2	1959 Award	2 8 0
25	*Cost of Striking Die for Medal*	— — —
—	Surplus of Income over Expenditure for year carried to Balance Sheet	9 17 0
£27		£12 5 0

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER 1959

1958 Figures £		£ s. d.
	ENDOWMENT FUND	
2617	Interest on Investments (Gross) ...	2848 15 6
1580	Interest on Investments (*less* Tax) ...	1775 2 2
67	Interest on Deposit Account at Bank (Gross) ...	102 14 7
994	Refund of Income Tax ...	1051 8 7
1500	Rents receivable ...	2000 0 0
£6758		£7778 0 10
	EDUCATION FUND	
10	Interest on Investments (Gross) ...	35 18 6
6	*Interest on Investments (less Tax)* ...	— — —
300	Contribution from Royal Aeronautical Society (Charter Scholarship) ...	300 0 0
225	Transfer from Edward Busk Studentship in Aeronautics ...	230 14 8
121	Transfer from Geoffrey de Havilland Memorial Fund ...	123 18 8
£662		£690 11 10
	IN AERONAUTICS	
£225	Interest on Investments (Gross) ...	£230 14 8
	MEMORIAL FUND	
£121	Interest on Investments (Gross) ...	£123 18 8
	MEMORIAL FUND	
81	Interest on Investments (Gross) ...	82 15 8
—	Contribution from Edward Busk Memorial Fund ...	18 0 0
19	*Excess of Expenditure over Income for year* ...	— — —
£100		£100 15 8
	MEMORIAL FUND	
25	Interest on Investments (Gross) ...	50 4 4
£25		£50 4 4
	MEMORIAL FUND	
5	Interest on Investments (Gross) ...	6 2 4
—	Contribution from Edward Busk Memorial Fund ...	5 0 0
£5		£11 2 4
	MEMORIAL FUND	
6	Interest on Investments (Gross) ...	5 19 4
—	Contribution from Edward Busk Memorial Fund ...	5 0 0
4	*Excess of Expenditure over Income for year* ...	— — —
£10		£10 19 4
	STUART FUND	
45	Interest on Investments (Gross) ...	52 12 4
£45		£52 12 4
	MEMORIAL FUND	
70	Interest on Investments (Gross) ...	84 17 4
£70		£84 17 4
	MEDAL FUND	
19	Interest on Investments (Gross) ...	22 18 0
1	*Excess of Expenditure over Income for year* ...	— — —
£20		£22 18 0
	MEMORIAL FUND	
11	Interest on Investments (Gross) ...	12 5 0
16	*Excess of Expenditure over Income for year* ...	— — —
£27		£12 5 0

Donations

The Council acknowledge with grateful thanks donations which have been received during 1959 from the following:—

Blackburn Aircraft Limited.
Bristol Aeroplane Company Limited.
de Havilland Holdings Limited.
Dowty Equipment Limited.
English Electric Group.
Hawker Siddeley Group.
Hunting Aircraft Limited.
Ministry of Aviation (formerly Ministry of Supply).
Rolls-Royce Limited.
Society of British Aircraft Constructors.
Vickers-Armstrongs (Aircraft) Limited.
Westland Aircraft Limited.

The Society has also received grants for Technical Work from:—

The Society of British Aircraft Constructors.
The Ministry of Aviation (formerly Ministry of Supply).

Obituaries, 1959

The Council regret to record the death of the following Members during the year:—

E. J. Arnsby (*Companion*)
Air Vice-Marshal G. B. Beardsworth (*Fellow*)
A. E. Berriman (*Fellow*)
H. E. Broadsmith (*Fellow*)
J. L. P. Brodie (*Fellow*)
J. Carter (*Associate Fellow*)
C. B. Collins (*Associate*)
Lt. Col. M. O. Darby (*Companion*)
W. J. L. Davies (*Associate Fellow*)
R. B. Elliott (*Associate Fellow*)
G. W. K. Frayling (*Associate Fellow*)
R. A. Frazer (*Fellow*)
Professor A. R. Fulton (*Fellow*)
G. D. S. Garrett (*Associate*)
Claude Grahame-White (*Companion*)
E. N. Grantham (*Associate Fellow*)
A. A. Hammond (*Associate Fellow*)
C. J. Hayward (*Associate Fellow*)
S. F. Hemsted (*Associate*)
F. H. Henstock (*Associate*)
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P. D. R. Luscombe (*Associate Fellow*)
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W. O. Manning (*Fellow*)
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J. A. Mollison (*Associate Fellow*)
R. B. C. Noorduyn (*Fellow*)
F. H. Parker (*Associate Fellow*)
Major H. W. Prance (*Associate Fellow*)
F. Rowarth (*Fellow*)
F. J. Samuely (*Companion*)
Sqn. Ldr. J. Satchell (*Associate Fellow*)
D. C. Smith (*Associate Fellow*)
F. W. Stock (*Associate*)
H. C. B. Thomas (*Fellow*)
Sir Henry Tizard (*Honorary Fellow*)
A. G. Treasure (*Graduate*)
E. de B. Valle (*Student*)
Group Captain C. T. Walkington (*Associate Fellow*)
F. W. Wardley (*Associate Fellow*)
L. W. Warner (*Fellow*)
The Rt. Hon. Viscount Weir of Eastwood (*Fellow*)
A. R. Weyl (*Associate Fellow*)
R. H. Williams (*Associate Fellow*)
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Reviews

ADVANCES IN AERONAUTICAL SCIENCES. *Proceedings of the First International Congress in the Aeronautical Sciences, Madrid, 8th-13th Sept. 1958. 2 Volumes. Pergamon Press, London, 1959. 1123 pp. Illustrated. £10.*

A scientific conference provides opportunities for scientists both to meet and discuss problems of common interest and also to learn what others are doing in adjoining fields. This is perhaps the most valuable aspect of the Madrid International Congress since personal contacts have made it easier at later dates to exchange views and further information by correspondence; and it is surprising what a stimulus these personal contacts usually provide. There is, however, another equally useful aspect which arises directly from the presentation of papers. As no one can attend the reading of more than a few of the papers and as most are incapable of absorbing at the time all that the papers contain, a published record is essential. New papers can then be read and the other papers studied in detail, both by those who attended the Congress and the many who were not so fortunate. It is in these last respects that the publication of the two volumes describing advances in aeronautical sciences is so valuable. The papers are collected in an excellent format, very readable and nicely laid out as regards text and illustrations. Moreover, we find, as is so often the case in the first proceedings of an International Congress, that leading scientists have been persuaded to describe either new work or to provide excellent summaries of the state of existing knowledge. As such, the Daniel and Florence Guggenheim Memorial Lecture on "Some Significant Developments in Aerodynamics since 1946" given by the Honorary President, Theodore von Kármán, is a classic contribution, in keeping with his practice on many previous like occasions. This lecture is outstanding in its wide range and in its numerous references to previously published work on aerodynamics. Many other papers have likewise extensive and useful bibliographies, a factor which adds greatly to their value.

The volumes have a comprehensive author and subject index. Unfortunately, it is a common practice in scientific and technical books of more than one volume to publish the index only in the last volume, which is so in the present instance. The extra ease of reference to users would well repay the slight increase of cost if the index were published in both volumes. The Foreword is published twice, yet each volume has its separate list of contents and nothing to indicate what is in the other volume, which has to be taken out of the shelf to find out. Moreover, finding many papers on hypersonic problems in Volume I, a reader would not suspect that Ferri's excellent review of some recent developments in this subject would be found by itself in the middle of the other volume. Apart from this, most papers on a given subject adjoin each other in the same volume.

After von Kármán's paper in Volume I, follow a number of others on supersonic and hypersonic flow and the associated thermal problems. Structural subjects include thermal stress, buckling of panels, vibration, flutter and jet reaction. Researches on noise reduction, guidance, control and navigation complete the list. The second volume includes papers on the control of the boundary layer, two on aeroelasticity, one on hypersonic flow, others on fluid motion problems, heat resistant materials and heat transfer, propulsion problems in space, V.T.O.L. and S.T.O.L. aircraft and two on the human factors in aeronautics.

A study of the majority of the individual papers points ways to new investigations in fields that are by no means fully explored. What will help in some cases is a clarification of terms coming slowly into use. von Kármán states his belief that a systematic nomenclature and classification of the new branches of combined fluid mechanics, electromagnetic theory and thermodynamics is yet lacking; in his reference to magnetofluidmechanics, written as one word, he mentions that the main interest arose from celestial problems which later leads him to include "heavenly turbulence" under this compound word. Elsewhere in other papers, the more generally accepted term—magnetohydrodynamics will be found, together with others such as Thermal-plasma and Magneto-plasma systems, dissociation mode and Fully catalytic wall, to mention only a few. To find such terms in these volumes, although well defined by individual authors, strengthens the contention of von Kármán. We have already drawn attention to Ferri's review. Experimental techniques under development for the investigation of hypervelocity flight are considered by Lukasiewicz, in relation to the characteristics of trajectories of special interest, in a lengthy paper where he draws a distinction between hypersonic and hypervelocity test facilities. The problems of simulating hypervelocity flight at low densities are also discussed in this informative paper. The dynamics of one much-discussed dissociating gas, oxygen, are dealt with by Lighthill and the Newtonian Flow Theory by Hayes. Supersonic propulsion is covered by four papers presented by Blackman, Moeckel, Roy and Thompson; inertial guidance by Draper and others; human limitations by Julian E. Ward and G. Melvill Jones. Thus the subjects of missiles and satellites, so much in people's minds today is well covered in these volumes. Noise too concerns us all; we find papers describing the investigations already undertaken by Rolls-Royce Ltd., what is being done on noise research in Canada and noise with respect to air transport. None of these last seem to promise more than a few decibels reduction of this modern nuisance. We cannot mention all the papers, but we must include two more that attracted our special interest: Aerodynamic design for supersonic speeds by Robert T. Jones and the comprehensive account by John P. Campbell about research on V.T.O.L. and S.T.O.L. aircraft in the U.S.A. These authors and subjects speak for themselves and support the conclusion that both volumes of the collected papers should be placed on library shelves.—J. L. NAYLER.

SUPERSONIC AND SUBSONIC AIRPLANE DESIGN. *Gerald Corning. Published privately at Box 14, College Park, Maryland, U.S.A., 1959. Distributed by Bailey Brothers and Swinfen, London. 454 pp. Diagrams. 70s.*

The problem of reconciling theory with practice dominates many of man's activities—including aircraft design. Theory is dealt with in text books and, in the case of recent developments, in periodicals and reports, but these are often of little immediate use to the designer. If, hopefully, he reads the end of a report for a summary of the practical implications of the work described, he may well find a differential equation! A valuable contribution is made by those able to convert formulae to tables and curves for the use of designers and to include the factors which, experience shows, are needed to bring theory and achievement into agreement.

The Royal Aeronautical Society has contributed by the publication of its Data Sheets. Some of these present, in easily used curves, the results of long calculations or of series of wind tunnel and flight measurements (*e.g.* profile drag of aerofoils, optimum climb techniques, lift increments of flaps). Others include recommended factors based on experience as in "Estimation of take-off and landing speeds." With the aid of good textbooks, reports and some digests in the form of data sheets, the designer can proceed.

Professor Corning of the University of Maryland has attempted to combine these into one textbook for the designer aimed at providing "for the engineers in industry and for use in the classroom" an "actual method of arriving at an airplane design." 60 per cent is devoted to basic aerodynamics, 20 per cent to stability and control and 20 per cent to structural requirements (American). Even within the large space devoted to aerodynamics the author is able to deal only superficially with many topics. We are told, for example, that ailerons are needed to provide a certain rate of roll and that they commonly cover "about 30 per cent of the chord and extend from about 65 per cent of the span outboard" but are given no help in choosing a section or plan form. That ineffectiveness at high speeds has led to the use of spoilers is also mentioned but no help in the design of spoilers is offered. Some chapters end with references to reports—almost all American—but many chapters have no references at all.

Let us admit that the task set by the author for himself, is almost incapable of solution. Much numerical information is, indeed, included and is most helpful to the design student. There seems little point, however, in outlining a difficulty, such as the need for spoilers to combat aeroelastic effects, without either giving data on spoilers or guiding the reader to reports on the subject.

The book is lithoprinted and published privately. The second edition, received in 1959 but undated, is apparently an enlarged version of the 1953 edition. The pages have been re-numbered on a chapter basis except for pages 429-453 which follow page 12:60. The style occasionally jars ("our entire airforce is practically composed of all supersonic aircraft, with the few subsonic bombers soon to be displaced by the faster supersonic ones") but the book is a gallant attempt at a difficult task.—A. H. YATES.

SPACE TECHNOLOGY. *Howard S. Siefert* (Editor). *John Wiley, New York, 1959; Chapman and Hall, London. Sectional pagination (total 1174), Illustrated. £9.*

An expensive book? Perhaps, but where else could be found 38 front line authors covering so wide a field so well? As one reads this handsomely produced volume, one's mind returns to the classical engineering works of David Alan Low, Salmon on materials, Pippard and Baker on structures. Has engineering extended so much that it can no longer be dealt with adequately by one or at most two authors per book? And if it has, and the writings of so many contributors have to be co-ordinated, how best can this be done? In the case of this book it was achieved by the modern technique of arranging a series of lectures —this ensures the material is prepared for a certain date—after which the separate chapters can be polished to ensure continuity and comprehensiveness. These lectures were given in early 1958, and the book was published in the autumn of 1959. It treats subjects both fundamentally and with practical examples, and being based on recent work is likely to remain valuable for a considerable time. The authors are men like Ehricke, Van Allen, Eggers, Kantrowitz, Buchheim; all well established in the forefront of the American space scene. Much of the writing is new; some has been published before, but it is very convenient to have so much material collected together in one volume.

How general is its treatment? It covers technology widely and enters briefly into the realms of metaphysics. It is even suggested, for example, that spaceflight will bring about a new renaissance, and could provide the medium by which mankind can emigrate from this planet when the sun dies—millions of years hence. A brief but authoritative astronomical outline is given, and there are some carefully revised solar system data contributed by Ehricke. At the less general end of the scale, there are many excellent specialist treatments — particularly the mathematical theories of trajectory optimisation (Fried of S.T.L.), and applications of trajectory optimisation to close earth satellite orbits and injection paths (Siry of N.A.S.A.).

The book is divided into five main sections: flight dynamics; propulsion and structures; communications, guidance and control; man-in-space (astro-biophysics); and present and future applications of space technology. The propulsion treatment was thorough and comprehensive (five chapters), but only one chapter was devoted to structural problems. More could have been said about materials, especially metals, and the unusual effects of some space environments such as high vacuum on alloys and lubricants and low temperature cycling on metals. Missile structural vibration, which is so important, so much misunderstood and so different from ground-based experience, might have received more than one chapter; and ground testing, reliability techniques and range engineering were not dealt with adequately. Nevertheless, such topics may give hope for authors who might otherwise feel that the last word has been written on this subject. The book is sound, comprehensive, interesting for individual specialists to read outside their own fields, and invaluable for consultation. References are plentiful.—J. E. ALLEN.

HYPERSONIC FLOW THEORY. *W. D. Hayes and R. F. Probstein. Academic Press, New York, 1959. 464 pp. Diagrams. $11.50.*

Hypersonic flow is a field in which progress has been very rapid in the past few years. This book will therefore be welcome as a review of the literature on this subject and as a source of useful references. However, it purports to be more than this—not only an advanced textbook, but a vehicle for the publication of much original work of the authors (in particular, that of W. D. Hayes). Whether a book could fulfil both these rôles is a debatable point, and here, if anywhere, lies the weakness of this otherwise admirable book. Much of this work will require early revision, in volume and emphasis if not in fundamental development. Although the presentation of original work is of value to the worker in the immediate field, it must detract from the whole as a textbook.

In general, the authors are concerned with developing the fundamental theory of hypersonic flow and in presenting the simplifications and complications introduced by high speed and/or Mach number. The theories of inviscid and viscous hypersonic flow are put forward, recourse to experimental results being made mainly for purpose of comparison. The empirical approaches to these problems which are all too readily available, are avoided. In this respect the book is not primarily designed for the engineer. It will prove of most value to the research worker, the teacher and student of advanced courses.

Of the ten chapters which comprise the volume, the first five are by the senior author (W.D.H.). In these chapters, the basic similitudes in inviscid hypersonic theory are discussed and the two main theories—the small distur-

bance theory and the Newtonian theory—are developed. With reference to the former theory, the similar solutions for expanding and contracting shock waves are discussed. Particularly useful is the statement of the one known analytic solution due to Sedov and Latter. The word "Newtonian" is used (for better or worse) to denote the flow solutions for infinite free stream Mach number and ratio of specific heats near one. This treatment of the bluff body problem is discussed in some detail.

The numerous numerical approaches to the bluff body problem are catalogued in Chapter 6, and the Russian work on the integral or Pohlhausen technique is described here, but the main part of the chapter is devoted to the various methods of attacking the problem by a marching technique, starting from a given shock shape. The comments on the validity of this approach are illuminating.

The next three chapters are devoted to the viscous problems. The derivation of the usual boundary layer equations to include real gas equilibrium thermodynamics and their subsequent development links a lot of hitherto widely dispersed methods. A clear exposition of the boundary layer interaction problem at hypersonic speeds follows.

The last chapter contains a necessarily incomplete discussion on rarefied gas flows and the free molecular results. This brings the book to the limits of present knowledge and to the beginning of what promises to be the most interesting aspect of this field.—N. C. FREEMAN.

Additions to the Library

Advances in Space Science. Volume I. F. I. Ordway (Editor). Academic Press, New York. 1959. 412 pp. Illustrated. 86s. *To be reviewed.*

Available Energy and the Second Law Analysis. E. A. Bruges. Butterworth, London. 1959. 124 pp. Diagrams. 25s. *To be reviewed.*

Basic Electronics. Parts 1-6. Van Valkenburgh, Nooker and Neville Inc. (for U.S. Navy). Technical Press, London. 1959 (originally 1955). 12s. 6d. per part. *To be reviewed.*

Birds and Fishes, The Story of Coastal Command. Sir Philip Joubert de la Ferté. Hutchinson, London. 1960. 224 pp. Illustrated. 25s. *To be reviewed.*

De Havilland Caribou, The. De Havilland Aircraft of Canada Ltd. A well-produced pamphlet describing one particular aircraft.

Fire Protection and the Maintenance of Aircraft. Fire Protection Association. 1959. 28 pp. 2s. A booklet produced to fill a gap in which there is no generally available literature. Part I deals with hangars, Part II with maintenance hazards. Appendix A is a bibliography and Appendix B a list of statutory requirements. The Association is at 31-45 Gresham St., London, E.C.2.

Handbook of Supersonic Aerodynamics. Section 16. Mechanics of Rarefied Gases. Navord Report 1488, Volume V. S. A. Schaaf and L. Talbot. U.S.G.P.O. 1959. $1.25. A new section of the well-known and much-used handbook from the Johns Hopkins University Applied Physics Laboratory.

New Zealanders with the Royal Air Force. Volume III. W/Cdr. H. L. Thompson. Dept. Internal Affairs: War History Branch. Wellington. 1959. 409 pp. Illustrated. No price. *To be reviewed.*

Operator Training in Industry. W. D. Seymour. Institute of Personnel Management. 1959. 52 pp. 7s. 6d. A broadsheet covering the training of unskilled and semi-skilled operatives. Its substance was originally presented as a series of lectures at Birmingham College of Advanced Technology.

Pratt and Whitney Aircraft Story, The. 1952. 173 pp. Illustrated. A second edition of a publication originally issued in 1950 on the firm's 25th anniversary.

Proceedings of the Royal Society. Series A. No. 1275. 1959. 88 pp. 18s. Thirteen papers in a discussion on space research under the leadership of H. S. W. Massey. Authors include Lovell, Hoyle Van Allen, King-Hele.

Process Integration and Instrumentation. Electrical Development Association. 1959. 204 pp. Illustrated. No price. No. 8 in the E.D.A. Electricity and Productivity Series. Information has been collected from many sources, resulting in chapters on such subjects as automatic control, sensing, actuators and servomotors, some 80 industrial applications, computers, quality control, etc. The Association is at 2 Savoy Hill, London, W.C.2.

Professional Qualifications in the Electronics Industry. C. M. Cade. Kelvin and Hughes Ltd. 14 pp. app. An analysis of qualifications commonly accepted as equivalent to University Honours and Pass Degrees.

Similarity and Dimensional Methods in Mechanics. L. I. Sedov, Maurice Holt and Morris Friedman. Academic Press, New York. (Infosearch, London). 1959. 361 pp. Illustrated. 5 gns. *To be reviewed.*

Small Gas Turbines. Arthur W. Judge. Chapman and Hall, London. 1960. 328 pp. Illustrated. 48s. *To be reviewed.*

Some Servo Mechanisms for Supersonic Aircraft. S. G. Glaze. Main Lecture given at the Gloucester and Cheltenham Branch of the Society on 3rd Dec 1959.

Statistics of Extremes. E. J. Gumbel. Columbia University, New York. (O.U.P., London). 1958. 375 pp. Diagrams. £6. This, the first book devoted wholly to statistics of extremes, is written by the Adjunct Professor of Industrial Engineering of Columbia University. It is "directed to statisticians and statistically minded engineers geophysicists and climatologists who may apply the findings in science, industry and technology". A brief indication is given of its application to *V-g* records and the fatigue of metals, but the book is primarily a theoretical one, which requires some prior knowledge of statistical analysis and probability theory.

Story of Flight, The. Dunlop Rubber Co. 20 pp. Illustrated. A short amply-illustrated history in pamphlet form, apparently intended as a "give-away".

Study of the Onset of Fatigue Damage due to Fretting, A. A. J. Fenner and J. E. Field. N.E. Coast Institution of Engineers and Shipbuilders, Newcastle. 1960. 45 pp. Illustrated. No price. A paper read to the Institution in January. The material investigated is aluminium alloy B.S.L.65 and the work was done at the National Engineering Laboratory (D.S.I.R.).

Supersonic and Subsonic Airplane Design. G. Corning. Published by the author. (Distributed by Bailey Bros. and Swinfen, London). Second Edition, 1959. 454 pp. Diagrams. 70s. *Reviewed in this issue,* p. 252.

Theory of Optimum Noise Immunity, The. V. A. Kotelnikov. McGraw-Hill London. 1959. 140 pp. Diagrams. 58s. A verbatim translation of a Moscow publication of 1956, which was essentially a 1947 doctorial thesis. It analyses the effects of additive Gaussian noise on communication systems and determines what can be done at the receiving end to minimise them. The primary intention is to establish the behaviour of communications systems at a level that is of practical use to the engineer.

I.A.S. Papers Presented at 28th Annual Meeting (New York 25th to 27th January 1960).

No. 60-54. Preliminary Flight Experiments with the Princeton University Twenty-foot Ground Effect Machine. W. B. Nixon and T. E. Sweeney.

No. 60-55. Electrical Space Propulsion, R. H. Boden.

Reports

AERODYNAMICS

Boundary Layer—*see also* Fluid Dynamics Thermo-Aerodynamics

The occurrence and development of boundary-layer separations at high incidences and high speeds. H. H. Pearcey. R. & M. 3109. 1960.
The manner in which the onset of the effects of boundary layer separation varies with Mach number for two-dimensional aerofoils is described, and the influence of section shape as far as is known is discussed. A brief qualitative description is given of the mechanism underlying the development of the separated flow and its effects, followed by a discussion of some of the ways in which this is likely to differ for swept-back wings at high speeds.—(1.1.4.2).

Investigation of the flow over a spiked-nose hemisphere-cylinder at a Mach number of 6·8. *D. H. Crawford. N.A.S.A. T.N. D*-118. *Dec.* 1959.
Schlieren photographs showed the effect of varying the spike length and Reynolds number upon the shape of the separated boundary and upon the location of transition. The heat transfer and pressure distribution over the body were then correlated with the location of the start of separation, the location of reattachment, and the location of the start of transition.—(1.1.2.4.×1.1.4.4.×1.9.2).

Measurements of pressure and local heat transfer on a 20° *cone at angles of attack up to* 20° *for a Mach number of* 4·95. *J. D. Julius. N.A.S.A. T.N. D*-179. *Dec.* 1959.
Data were obtained in a Reynolds number range of 14×10^6 to 75×10^6 per foot based on free-stream conditions. The measured pressures were compared with the first and second-order approximations of exact cone theory and with Newtonian and modified Newtonian theory.—(1.1.1.4×1.1.3.4×1.9.1).

Charts for determining skin-friction coefficients on smooth and on rough flat plates at Mach numbers up to 5·0 *with and without heat transfer. D. W. Clutter. Douglas Report E.S.* 29074. *April* 1959.
The Nikuradse-Prandtl-Schlichting charts that show the variation of skin friction coefficients with Reynolds number and degree of surface roughness are extended to compressible flows for: Mach number ranging from 0 to 5·0; Transition-point location from zero (fully turbulent) to 50-per cent chord; Two wall temperatures, insulated plate and wall temperature equal to the free-stream temperature. The relations for determining the coefficients of total skin friction, local skin friction and heat transfer are also presented. They have been experimentally verified through a Mach number of 5·0.—(1.1.2.4×1.9.1).

Theoretische und experimentelle Beiträge zur Grenzschichtströmung. F. Schultz-Grunow. Forsch. des Landes Nordrhein-Westfalen. 684. 1959.
Flow visualisation techniques, the origin of vortices in boundary layers, the stability of Couette flow between a rotating outer and fixed inner cylinder and a compound macromolecular solution in shear flow are discussed.—(1.1.0.1×1.4).

Compressible Flow—*see also*— Fluid Dynamics Loads

Supersonic flow past a family of blunt axisymmetric bodies. M. D. Van Dyke and H. D. Gordon. N.A.S.A. T.R. R-1. 1959.
Some 100 numerical computations have been carried out for unyawed bodies of revolution with detached bow waves. The gas is assumed perfect with $\gamma=5/3$, 7/5, or 1. Free-stream Mach numbers are taken as 1·2, 1·5, 2, 3, 4, 6, 10 and ∞. The results are summarised with emphasis on the sphere and paraboloid.—(1.2.3.2).

An investigation of some aspects of the sonic boom by means of wind-tunnel measurements of pressures about several bodies at a Mach number of 2·01. *H. W. Carlson. N.A.S.A. T.N. D*-161. *Dec.* 1959.
An investigation of some aspects of the sonic boom has been made with the aid of wind tunnel measurements of the pressure distributions about bodies of various shapes. The tests were made at a Mach number of 2·01 and at a Reynolds number per foot of $2\cdot5\times10^6$. Measurements of the pressure field were made at orifices in the surface of a boundary layer bypass plate. The models which represented both fuselage and wing types of thickness distributions were small enough to allow measurements as far away as 8 body lengths or 64 chords.—(1.2.2.2×1.4×5.6).

The sound generated by interaction of a single vortex with a shock wave. H. S. Ribner. UTIA Report 61. *June* 1959.
The passage of a columnar vortex "broadside" through a shock is investigated. The vortex is decomposed (by Fourier transform) into plane sinusoidal shear waves disposed with radial symmetry. The plane sound waves produced by each shear wave-shock interaction, known from previous work, are recombined in the Fourier integral.—(1.2.3.2).

Controls—*see also*— Stability and Control Wings and Aerofoils

Static tests of an external-flow jet-augmented flap test bed with a turbojet engine. M. P. Fink. N.A.S.A. T.N. D-124. *Dec.* 1959.
Exploratory tests have been made on a static set-up to determine the turning efficiency of an external-flow jet-augmented flap immersed in the flow from a flattened tailpipe on a turbo-jet engine. Several tailpipes with various width-height ratios were evaluated and the flap-slot gap was varied through a range of heights for several entrance ramp angles. Wake temperatures at the flap were taken for several tailpipe configurations.—(1.3.4×27.1×1.5.1).

The effects of an inverse-taper leading-edge flap on the aerodynamic loading characteristics of a 45° *sweptback wing at Mach numbers to* 0·90. *F. A. Demele. N.A.S.A. T.N. D*-138. *Dec.* 1959.
An investigation has been conducted to determine the wing-surface pressures and aerodynamic loading associated with deflection of an inverse-taper leading edge flap on a swept-wing and body combination. Data are presented for flap angles to 16° at Mach numbers of 0·60 to 0·90 with a Reynolds number of 3·2 million and at a Mach number of 0·25 with a Reynolds number of 15·0 million.—(1.3.7×1.6.1).

Lift and drag characteristics at subsonic speeds and at a Mach number of 1·9 *of a lifting circular cylinder with a fineness ratio of* 10. *V. E. Lockwood and L. W. McKinney. N.A.S.A. T.N. D*-170. *Dec.* 1959.
Several full-span flaps attached to the bottom surface of the cylinder and varying in chord from 0·004 to 0·300 cylinder diameters were used as lift-generating devices. Most of the tests were made with the flaps at the 50 per cent chord station, but in a few tests the chordwise location was one of the variables. The investigation covered a subsonic Mach number range from 0·07 to 0·80 and Reynolds number range from 355,000 to 1,600,000. A limited amount of data was also obtained at a Mach number of 1·9.—(1.3.4).

Fluid Dynamics—*see also* Boundary Layer Compressible Flow

*Axi-symmetric magneto-gas dynamic channel flow. F. D. Hains and Y. A. Yoler. Boeing Doc. D*1-82-0008. *Aug.* 1959.
The channelling effect of the magnetic field produced by a circular loop of wire on the steady state flow at low magnetic Reynolds numbers of an electrically conducting compressible gas in a circular channel of constant radius co-axial with the magnetic field is analysed. Numerical results to the exact equations are given when the flow is supersonic. Formal solutions are given for subsonic and supersonic flow linearised for small values of the magnetic interaction parameter. Shock-tube investigations of wall pressures and wall temperatures are discussed.—(1.4.4×1.5.1.1).

Axi-symmetric hydromagnetic channel flow. F. D. Hains et al. *Boeing Doc. D*1-82-0025. *Aug.* 1959.
This paper is a version of Boeing Doc. D1-82-0008 (*see above*) given at the ARS—Northwestern Gas Dynamics Symposium, Evanston, Illinois, August 1959. Most of the material is common to both, the author's abstracts are virtually identical.—(1.4.4×1.5.1.1).

Contribution a la théorie des ondes de choc en magnétodynamique des fluides. P. Germain. O.N.E.R.A. Pub. 97. 1959. (*In French*).
Shock waves in magneto-hydrodynamics are studied. These are considered as singularities in the flow where various mechanisms of dissipation (viscosity, thermal conductivity, electrical resistance) can be brought into play. The existence of a strong shock, the instability (and consequent non-existence) of intermediate shocks, and the possibility of a weak stable shock, are established.—(1.4.4×1.2.3.2).

*Séminaire d'Aérothermique de la Faculté des Sciences de Paris. E. A. Brun. Pubs. Sc. et Tech. N.T.*85. 1959. (*In French*).
Proceedings of the Séminaire d'Aérothermique de la Faculté de Sciences de Paris for 1957-58. The subjects are: rarified gases, shock waves, three-dimensional laminar boundary layers, detonation in gases and behaviour of fluid particles.—(1.4×1.2.3.2×1.1.1.1).

INTERNAL FLOW—*see also* CONTROLS
FLUID DYNAMICS
TESTING AND INSTRUMENTS

Investigation of the effect of a guide-vane-rotor combination on inlet total-pressure distortions in a compressible fluid. G. C. Ashby. N.A.S.A. T.N. D-123. *Dec.* 1959.
An experimental investigation has been conducted in a compressible fluid to determine the effectiveness of having a 90° included angle between the absolute and relative-flow directions at the inlet of a compressor in reducing an inlet total-pressure distortion. For these tests the average relative Mach number was 0·65 and the average density ratio across the rotor was approximately 1·12.—(1.5.2.2×27.1).

Über die Auslegung zweistufiger Heisswasserejektoren. O. Lutz und E. Riester. D.F.L. Bericht 114. 1959. (*In German*).—(1.5.1.4).

LOADS—*see also* CONTROLS

Working charts for rapid prediction of force and pressure coefficients on arbitrary bodies of revolution by use of Newtonian concepts. R. W. Rainey. N.A.S.A. T.N. D-176. *Dec.* 1959.—(1.6.1).

*Forces on wing-fuselage combinations in supersonic flow. J. H. Clarke. Boeing Doc. D*1-82-0018. *Aug.* 1959.
Reverse-flow relations are used to provide convenient expressions for the aerodynamic forces which act on a general wing-fuselage combination in supersonic flow. The drag, lift, spanwise and chordwise lift distributions, and wing moments are treated. Consideration is given to available methods and results, including tables, which apply to the wing-fuselage interference problem, and reverse-flow relations are then employed to effect desirable changes in the defining force expressions by introducing wings or fuselages in the reverse flow.—(1.6.1×1.2.3.1).

A probability analysis of coincident gust and manoeuvre loads in low-flying aircraft. S. D. Baxter et al. *N.R.C. Report LR*-264. *Nov.* 1959.
The basic data used refer to an aircraft of 30,000 pounds all-up weight, a mean aerodynamic chord of 10·4 ft., and a wing loading of 55 lb./ft.^{2} The aircraft is assumed to be travelling at 350 knots at an altitude of 500 feet. The mathematical problem was to obtain the frequency distribution of the joint occurrence of a gust and manoeuvre and from this to calculate the "hours to equal or exceed" pre-assigned load levels. Results are obtained by two methods of solution, one a purely mathematical approach, and the other electrical simulation.—(1.6.2×1.6.3×33.11).

PERFORMANCE

Improvement of the approach and landing characteristics of modern fighters. J. Czinczenheim and P. Jaillard. AGARD Report 225*T. Oct.* 1959.
High speed aircraft have led to increased runway lengths and have also made landing more difficult and less precise. To have large numbers of airfields available, dispersed to improve efficiency and facilitate protection, cement runways should be replaced by short grass ones. Reasons for deterioration in low speed performance, and ways in which this can be remedied, are discussed.—(1.7×5×6.1).

STABILITY AND CONTROL—*see also* HELICOPTER AERODYNAMICS
AIRCRAFT OPERATION

An exploratory investigation in a ballistic range of the stability derivatives of a simple airplane configuration at low supersonic speeds. C. E. De Rose and A. G. Boissevain. N.A.S.A. T.N. D-139. *Dec.* 1959.
Tests were conducted on models having two planes of mirror symmetry in a seven station ballistic range at Mach numbers of 1·2 to 1·4 and Reynolds numbers of $0{\cdot}8\times10^6$ to $1{\cdot}0\times10^6$ (based on wing chord). Primary static and dynamic stability derivatives obtained from flights with negligible rolling velocity effects compared fairly well with existing theory.—(1.8.0.2).

Single-degree-of-freedom simulator investigation of effects of summing display-instrument signals on man-machine control. J. W. McKee. N.A.S.A. T.N. D-148. *Dec.* 1959.
A study was undertaken to evaluate performance obtained with a simulated vehicle having poor stability, a proportional acceleration control, and an instrument responding to displacement or to summed displacement, velocity, and acceleration information.—(1.8.0.1×1.3.6).

A flight study of the conversion maneuver of a tilt-wing V.T.O.L. aircraft. L. P. Thomas. N.A.S.A. T.N. D-153. *Dec.* 1959.
A study of longitudinal data is presented which reveals the nature of the task of flying a tilt-wing vertical take-off and landing aircraft through the conversion manoeuvre in level flight and favourable weather and visibility conditions.—(1.8.2.1).

Analytical investigation of effect of spin entry technique on spin and recovery characteristics for a 60° *delta-wing airplane. S.H. Scher* et al. *N.A.S.A. T.N. D*-156. *Dec.* 1959.
A high-speed digital computer study has been made to investigate the effects of differences in full-scale aeroplane and spin-tunnel model testing techniques on spins and recoveries.—(1.8.3.1).

Flight investigations of automatic stabilisation of an airplane having static longitudinal instability. W. R. Russell et al. *N.A.S.A. T.N. D*-173. *Dec.* 1959.—(1.8.2.1×13.2.×5).

Jet effects on longitudinal trim of an airplane configuration measured at Mach numbers between 1·2 *and* 1·8. *R. F. Peck. N.A.S.A. T..N D*-177. *Dec.* 1959.—(1.8.2.1×1.6.1).

The interpretation of nonlinear pitching moments in relation to the pitch-up problem. G. S. Campbell and J. Weil. N.A.S.A. T.N. D-193. *Dec.* 1959.
Equations are presented for calculating the dynamic behaviour of aeroplanes having arbitrarily nonlinear aerodynamic characteristics. Application of the methods derived is directed towards a study of some of the factors affecting the severity of pitch-up motions encountered by aeroplanes having regions of reduced stability. Brief consideration is also given to the effectiveness of automatic stabilisation devices in reducing pitch-up severity.—(1.8.2.1).

Comparison of some experimental and theoretical data on damping-in-roll of a delta-wing body configuration at supersonic speeds. L. T. Conlin and K. J. Orlik-Rückemann. N.R.C. Report LR-266. *Dec.* 1959.
The damping-in-roll derivative of a wing-body combination consisting of a triangular wing of aspect ratio 2 and a body of revolution, with and without a fin, was measured at two oscillation frequencies using the free oscillation technique. The results were compared with theory and other experiments in wind tunnel and aeroballistics range.—(1.8.2.2).

Half-model measurements of longitudinal force and moment characteristics of AGARD model "B" at subsonic and supersonic speeds. J. G. Laberge. N.R.C. Report LR-267. *Dec.* 1959.
Longitudinal force and moment characteristics of AGARD model "B" as measured on a half model in the N.A.E. 30-in. × 16-in. high speed wind tunnel, over a Mach number range from 0·375 to 2·03 are presented.—(1.8.2.2×1.10.2.2).

THERMO-AERODYNAMICS—*see also* BOUNDARY LAYER
TESTING AND INSTRUMENTS
MATERIALS

Methods of predicting laminar heat rates on hypersonic vehicles. R. J. Wisniewski. N.A.S.A.T.N. D-201. *Dec.* 1959.
A summary of some of the simplest and best available laminar heat transfer theories for flow in thermodynamic equilibrium is presented. In some cases the effects of frozen flow are included. Emphasis is placed on the proper methods of obtaining heating rates to hypersonic bodies, wings, and control surfaces. The effects of yaw and the determination of the inviscid flow field are also considered.—(1.9.1×1.1.1.4).

Stability of a horizontal fluid layer with unsteady heating from below and time-dependent body force. A. W. Goldstein. N.A.S.A. T.R. R-4. 1959.
The stability of a horizontal layer of fluid heated unsteadily from below and subjected to a time-dependent body force field was investigated theoretically, assuming an incompressible fluid with small density changes resulting from heating. A stability criterion is developed and used to calculate critical Rayleigh numbers.—(1.9.3).

WINGS AND AEROFOILS—*see also* STABILITY AND CONTROL

A note on the drag due to lift as influenced by a jet flap on a wing of finite span. S. B. Berndt. F.F.A. Report 85. 1959.—(1.10.1.2×1.3.4).

HELICOPTER AERODYNAMICS—*see also* MATHEMATICS

Full-scale wind-tunnel investigation of the longitudinal characteristics of a tilting-rotor convertiplane. D. G. Koenig et al. *N.A.S.A. T.N. D*-35. *Dec.* 1959.
Results were obtained for the XV-3 convertiplane. Aircraft configuration variables were angle of attack, rotor-pylon angle, power, and longitudinal control. With the exceptions of a few tests made at or near zero airspeed, most of the tests were made between approximately 60 and 120 knots. Rotor characteristics, aircraft static stability, and several conversion procedures are analysed.—(1.11.2×1.8.2.2).

Dynamic-model investigation of the damping of flapwise bending modes of two-blade rotors in hovering and a comparison with quasi-static and unsteady aerodynamic theories. M. A. Silveira and G. W. Brooks. N.A.S.A. T.N. D-175. *Dec.* 1959.—(1.11.1×2×33.1.2).

TESTING AND INSTRUMENTS—*see also* AEROELASTICITY

The design and use of interferometers in aerodynamics. L. H. Tanner. R. & M. 3131. 1959.
A practical account of the problems which are encountered in the design and use of interferometers on wind tunnels and shock tubes, and in the analysis and interpretation of interferograms is given. Topics covered include the design of frame and suspension, mirror mounts and adjustments, the choice of adjustable mirrors and the effects of passing the compensating beam through the tunnel or outside it. An account of the range, sensitivity and relative merits of the Mach-Zehnder and Twyman-Green interferometers is given, and the permissible source aperture and duration with those used for Schlieren photography are compared. A section on factors affecting accuracy deals with temperature changes and stress in the windows, convection currents and vibration, side-wall boundary layers, unsteady flow and loss of total pressure through shock waves and in dead-air regions.—(12.2.4×1.12.5).

Development of a thin film heat-transfer gauge for shock-tube flows. B. W. Taylor. U.T.I.A. Tech. Note 27. *June* 1959.
The use of liquid platinum paint for the manufacture of thin film resistance thermometers has been investigated and films so made have been used in the measurement of heat transfer rates in the UTIA 2×2 inch strong shock tube. The heat transfer model was a circular cylinder placed normal to the flow direction and having a thin film drawn at its stagnation line. The response of this thin film to the hot gas flow generated in the shock tube was used to determine heat transfer rates using the results of classical heat conduction theory. These heat transfer rates were compared with those predicted theoretically by L. Lees, and they were also used to calculate a value for the stagnation temperature of the flow.—(1.12.6×1.12.1.3×1.9.1).

Temperature response of a hot-wire anemometer to shock and rarefaction waves. S. G. Datar. U.T.I.A. Tech. Note 28. *June* 1959.
An investigation has been made of the temperature response of a hot-wire anemometer to incident and reflected shock and rarefaction waves. The measured temperatures are in good agreement with theory for very weak waves, but the agreement becomes progressively worse as the wave strength is increased.—(1.12.6.3×1.12.1.3.×1.2.3.2).

Construction et étalonnage d'une soufflerie a gaz trés raréfié. F. M. Devienne et al. *Pubs. Sc. et Tech.* 354. 1959.
The construction of a wind tunnel in which the static pressure can be varied between 0.1 and several microns of mercury is discussed. The wind tunnel has been calibrated and the results show that for air, the Mach number in the neighbourhood of the nozzle axis is of the order of 4.—(1.12.1.3).

Sur quelques problèmes posés par l'expérimentation en soufflerie aérodynamique. A. Martinot-Lagarde. Pubs. Sc. et Tech. 353. 1959. (*In French*).
The experimental determination of derivatives is discussed. By the principal of available energy the energy dissipated in a high speed wind tunnel is studied, and on an incompressible flow basis, the profile of a wind tunnel contraction at its exit is calculated. Similarity of internal transonic flow, spinning experiments in vertical wind tunnels and results of wind tunnel and flight testing are compared.—(1.12.1.1×1.12.1.2×1.5.1.4).

Design and operation of a continuous-flow hypersonic wind tunnel using a two-dimensional nozzle. H. M. Schurmeier. AGARDograph 38. *May* 1959.
The design and operation of a conventional hypersonic wind tunnel using a two-dimensional nozzle requires the solution of many engineering problems associated with the high stagnation temperatures and pressures and critical dimensional tolerances. These solutions are outlined in some detail.—(1.12.1.3×1.5.1.4).

AEROELASTICITY

See also AERODYNAMICS—HELICOPTER AERODYNAMICS

The determination of the flutter speed of a T-tail unit by calculations, model tests and flight flutter tests. J. C. A. Baldock. AGARD Report 221. *Oct.* 1959.
The comprehensive investigation made to determine the fin flutter speed of the Handley Page Victor is described. This investigation included low speed wind tunnel flutter model tests, calculations and flight flutter tests on the full scale aircraft. General observations are made with regard to the value of low speed wind tunnel flutter models and the safety aspect of flight flutter tests.—(2).

Flutter investigations in high-speed wind tunnels. G. Scruton and E. P. I. Windsor. AGARD Report 222. *Oct.* 1959.
A practical application of the similarity requirements to an investigation to determine the transonic flutter characteristics of a tail unit of a specific aircraft is described.—(2×1.12.1.2×1.12.1.3).

AIRCRAFT

See HYDRODYNAMICS

DESIGN AND CONSTRUCTION

Advanced cockpit instrumentation. J. Anast. AGARD Report 235. *May* 1959.
The development of an integrated cockpit instrumentation system to meet the requirements of increased speed, increased mission complexity, and the ever-changing demands of all-weather operation is described.—(4.2.1×18).

AIRCRAFT OPERATION

See also AERODYNAMICS—COMPRESSIBLE FLOW
PERFORMANCE
STABILITY AND CONTROL
AIRPORTS

An analog study of an airborne automatic landing-approach system. J. J. Adams. N.A.S.A. T.N. D-105. *Dec.* 1959.
An analogue study has been made of an automatic approach-control system which uses error information obtained with a simple radar target located at the end of the runway and a radar tracking set and attitude-measuring equipment carried in the aeroplane. The radar and attitude information was assumed to be free of any lag or dynamics. Most of the nonlinearities introduced by radar and gyro gimbal effects were included. The effects of various initial conditions and disturbances such as flap deflection, gust disturbances, and radar noise were investigated.—(5×1.8.0.1).

AIRPORTS

See also AERODYNAMICS—PERFORMANCE
STABILITY AND CONTROL

Emergency stopping of aircraft which over-run airfield runways. J. Thomlinson. AGARD Report 266. *Oct.* 1959.
Many of the various ways for stopping aircraft which over-run an airfield runway are discussed. Mechanical schemes are considered where special fittings, such as an arresting hook, are provided on the aircraft, and also where no such fittings are provided. Aircraft "catching" devices, such as arresting wires and barrier nets, are examined and the energy absorption systems which might be used are described.—(6.5×5.3).

EXTRA-ATMOSPHERIC TECHNOLOGY

Rocket measurements of the electron concentration in the ionosphere by means of an ultra-short wave dispersion interferometer. K. I. Gringauz. R.A.E. Lib. Trans. 861. *Dec.* 1959.
Electron density as a function of height is deduced from rocket flights. The phase difference between two coherent waves transmitted from the rocket on frequencies of 144 and 48 Mc/s was recorded at two points, from which the electron density was deduced.—(8×11×25).

Some notes on attitude control of earth satellite vehicles. W. Gillespie et al. *N.A.S.A. T.N. D*-40. *Dec.* 1959.
The problem of matching satellite mission stabilisation requirements with attitude-control-system capabilities is investigated. The probable missions that may require attitude control of the

satellite or its components and a variety of possible stabilisation methods are considered. The methods are compared with respect to mission suitability, accuracy, weight, power requirements, development effort, and reliability. An improved version of spin stabilisation is described and recommended for certain missions.—(8.2 × 1.8.0.1).

ELECTRONICS

See also EXTRA-ATMOSPHERIC TECHNOLOGY
MISSILES

Plasma acceleration by use of guided microwaves. R. V. Hess and K. Thom. N.A.S.A. T.N. D-46. Dec. 1959.
A method is explored which makes use of the radiation pressure of microwaves intensified in a resonant cavity as driving pressure. The success of the method depends on the recent development of microwave generators of extreme power outputs which in the near future should reach 100 megawatts.—(11).

FLIGHT TESTING

See AERODYNAMICS—STABILITY AND CONTROL

HYDRODYNAMICS

A brief investigation of the effect of waves on the take-off resistance of a seaplane. E. J. Mottard. N.A.S.A. T.N. D-165. Dec. 1959.
An evaluation was made of the resistance of a high-speed seaplane in waves of three heights. Various conditions were investigated for a seaplane having a dead-rise angle of 20°, a length-beam ratio of 15, and a wing loading of 120 lb./ft.^{2}.—(17 × 3.10).

INSTRUMENTS AND EQUIPMENT

See also DESIGN AND CONSTRUCTION

Flight tests of an experimental helicopter rotor blade electrical de-icer. J. R. Stallabrass. N.R.C. Report LR-263. Nov. 1959.
A sprayed metal in resin rotor blade de-icing mat employing the spanwise shedding principle was tested on a helicopter in flight under simulated icing conditions.—(18.4 × 29.3).

Combined analog-digital simulation of engineering problems. F. W. Pruden. N.R.C. Report MK-6. Oct. 1959.
A simple, but realistic dynamic system is considered, and the relative advantages of analogue and digital methods of solution are investigated. The coupling of analogue and digital machines is discussed, and the relevant sampled-data theory is introduced. The stability of such combined systems in calculations is considered. Examples of combined calculations are given.—(18.1 × 22).

MATERIALS

Graphite as a structural material in conditions of high thermal flux. A. J. Kennedy. CoA Report 121. *Nov.* 1959.
The state of fundamental knowledge on the subject of graphite and the graphitisation process is reviewed. The present state of development of the methods of manufacture is examined. Considerations relating to thermal shock, creep and fabrication are surveyed.—(21.2.2).

Compressive and tensile creep of 7075-T6 *and* 2024-T3 *aluminum-alloy sheet. G. J. Heimerl and J. Farquhar. N.A.S.A. T.N. D-160. Dec.* 1959.
Results are presented of compressive and tensile creep tests of 7075-T6 and 2024-T3 aluminium-alloy sheet at 300°, 375°, 450° and 600° F.—(21.2.3).

Calculated effective thermal conductivities of honeycomb sandwich panels. R. T. Swann. N.A.S.A. T.N. D-171. Dec. 1959.
The steady-state temperature distribution through honeycomb-type sandwich panels is calculated with simultaneous radiation and conduction. Based on this temperature distribution, the heat which will be transmitted is calculated. An effective thermal conductivity is defined, and calculated results are presented in dimensionless form. The effect of heat transmission through the air in the cells is briefly considered. The calculated results are compared with available experimental results.—(21.2.3 × 1.9.1).

Application of Morse potential function to cubic metals. L. A. Girifalco and V. G. Weizer. N.A.S.A. T.R. R-5. 1959.
The Morse parameters for the pairwise interaction of atoms in cubic metals were calculated from experimental values of the energy of cohesion, the lattice constant, and the compressibility.—(21.1).

Brittle fracture and the yield point phenomenon. N. Louat and H. L. Wain. A.R.L. Report Met 32. *April* 1959.
A modified theory of Cottrell Locking is further developed and compared qualitatively, and where possible quantitatively, with experiment. A simple inversion of the equation relating yield point to testing temperature leads to a condition for brittle fracture which is examined in the light of recent experimental work, particularly on iron and steel, molybdenum and chromium.—(21.2).

MATHEMATICS

See also—INSTRUMENTS AND EQUIPMENT
MISSILES

Derivation and tabulation of molecular integrals. R. C. Sahni and J. W. Cooley. N.A.S.A. T.N. D-146. Dec. 1959.
A study of integrals required in the computation of wave functions of atoms and diatomic molecules is presented. The wave functions, thus calculated, can be used to study a variety of molecular properties such as energies, polarisabilities, susceptibilities, and transition moments. Tabulated material for overlap, nuclear-attraction, kinetic energy, potential energy, Coulomb, hybrid, and exchange integrals is presented in supplements.—(22.1).

Méthodes topologiques appliquées a l'électronique. L. Sideriades. Pubs. Sc. et Tech. N.T. 84. 1959. (*In French*).—(22.1 × 11).

Éléments des calculs d'interpolation. D. Cot. Pubs. Sc. et Tech. B.S.T. 123. 1959. (*In French*).—(22.1).

Algebraic topology and networks. B. Langefors. S.A.A.B. T.N. 43. *July* 1959.
The elements of algebraic topology are introduced by means of examples from built-up systems of the simplest kind, *e.g.* electric networks. Only some small results are believed to be new but the subject has been treated in such a way as is believed to provide a basis for later extensions. Such extensions may be expected in the direction of applications to more general built-up systems such as elastic structures.—(22).

MISSILES

See also—EXTRA-ATMOSPHERIC TECHNOLOGY
STRUCTURES—THEORY AND ANALYSIS

Use of the Doppler effect for determining the parameters of the orbit of artificial earth satellites. V. A. Kotel'nikov et al. *R.A.E. Lib. Trans.* 860. *Dec.* 1959.
The Doppler effect is studied for three types of transmitter motions. Firstly, a transmitter in rectilinear motion moving at a constant velocity, secondly, rectilinear motion with uniform acceleration and thirdly, a transmitter moving along a curved trajectory. The variation in received frequency is determined, and methods presented to determine the time of closest approach, the velocity and range of the transmitter. Experimental observations were made on the first Russian artificial earth satellite and the parameters of the orbit determined. The accuracy of the method is discussed.—(25.3 × 11 × 22.2).

Graphical trajectory analysis. A. S. Boksenbom. N.A.S.A. T.N. D-64. Dec. 1959.
A simple graphical method for two-body trajectory problems is presented. The one basic graph used is composed simply of circles and straight lines. All features of trajectories appear on this map.—(25.2 × 22.2).

Reflection characteristics of artificial satellites constructed in the form of inflated polyhedrons. A. R. Sinclair. N.A.S.A. T.N. D-174. Dec. 1959.
Tests were made of inflated polyhedral shapes of thin aluminium-coated plastic to determine their suitability as artificial earth satellites having enhanced visibility as a result of bright flashes of reflected light from the facets.—(25.4).

A three-stage solid-fuel sounding rocket system suitable for research at altitudes near 200 *nautical miles. W. L. Dickens and E. C. Hastings. N.A.S.A. T.N. D-219. Dec.* 1959.
A three-stage solid fuel sounding rocket system, which has the capability of carrying an 81·5lb. payload to an altitude of 253 nautical miles is discussed. Data from two tests are presented. The estimated effects of launch angle, coast time between first-stage burn-out and second-stage ignition, payload, and headwinds and tailwinds on performance are discussed.—(25 × 27.3).